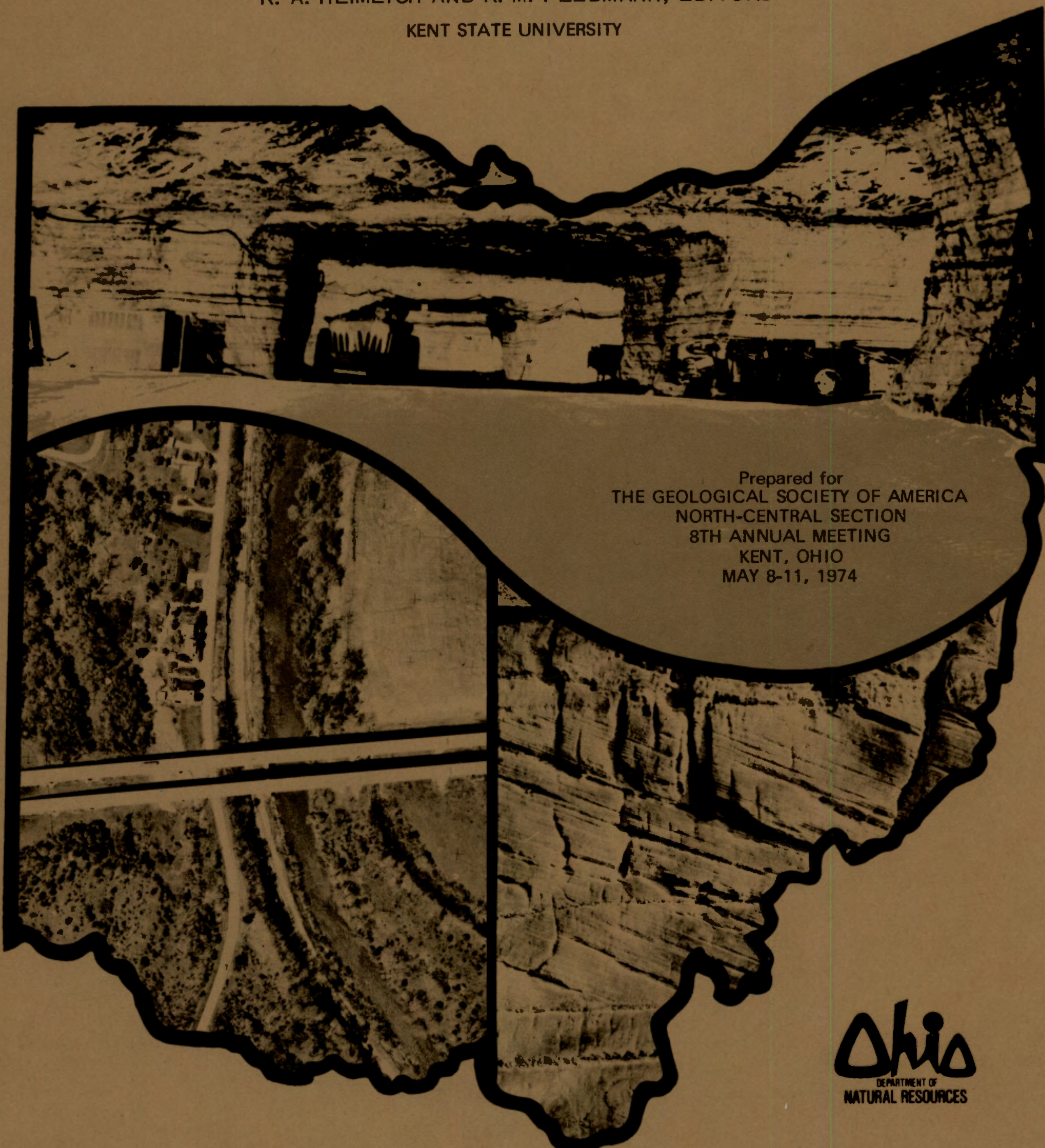
DIVISION OF GEOLOGICAL SURVEY

GUIDEBOOK NO. 2

SELECTED FIELD TRIPS IN NORTHEASTERN OHIO

R. A. HEIMLICH AND R. M. FELDMANN, EDITORS

KENT STATE UNIVERSITY



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SELECTED FIELD TRIPS IN NORTHEASTERN OHIO

edited by

R. A. Heimlich and R. M. Feldmann

Columbus
1974

GEOLOGY SERVES OHIO

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SELECTED FIELD TRIPS IN NORTHEASTERN OHIO

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R. A. Heimlich and R. M. Feldmann

INTRODUCTION

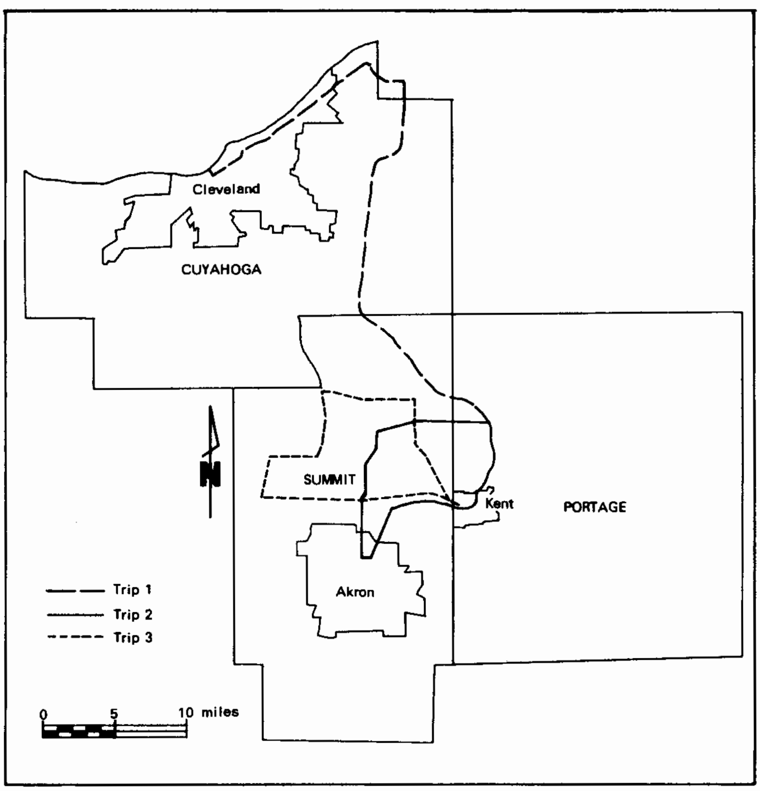
This guidebook was prepared for field trips to be conducted as part of the annual meeting of the North-Central Section of the Geological Society of America, May 8-11, 1974. The meeting is sponsored by the Department of Geology at Kent State University. The three trips were selected to bring emphasis to diverse aspects of the local geology. Locations of the trips, all within the Cleveland-Akron area, are shown on the accompanying map.

Trip 1.—General geology of the International Salt Company Cleveland Mine, Cleveland, Ohio - R. A. Heimlich, Ronald W. Manus, and C. H. Jacoby. Objective: to examine the stratigraphy and structure of Silurian halite deposits exposed in an active underground mine and to witness the drilling, recovery, and processing methods used.

Trip 2.—Sedimentary environments of the Lower Pennsylvanian Sharon Conglomerate near Akron, Ohio - A. H. Coogan, R. M. Feldmann, E. J. Szmuc, and J. V. Mrakovich. Objective: to study the textures and structures of a Pennsylvanian clastic unit, exposed at two localities, for the purpose of interpreting its depositional environment in terms of either the deltaic (meandering stream) or braided stream model.

Trip 3.—Engineering and Pleistocene geology of the lower Cuyahoga River valley - George Gardner, Arthur H. Wittine, Murray R. McComas, Barry B. Miller, and Ronald W. Manus. Objective: to examine the stratigraphy of Pleistocene glaciolacustrine deposits within a commercially undeveloped portion of a river valley and to demonstrate the relationship between the deposits and current slope-stability problems in the area.

R. A. Heimlich and R. M. Feldmann, editors



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FIELD TRIP NO. 1

GENERAL GEOLOGY OF THE INTERNATIONAL SALT COMPANY CLEVELAND MINE, CLEVELAND, OHIO

by

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INTRODUCTION

Of the more than 45 million tons of salt produced annually in the United States (Brobst and Pratt, 1973), Ohio supplies on the order of 6 million tons or approximately 13 percent of the national total. As one of the leading salt producers in the country, Ohio is next only to Texas and Louisiana. Primary production in the state is derived from four solution-mining operations and two underground mines (fig. 1). The Morton Salt Company Fairport Harbor Mine and the International Salt Company Cleveland Mine (Whiskey Island) produce roughly equal amounts of salt which in 1970 amounted to a little more than half the total state production (Clifford, 1973). Prior to the opening of these underground mines in 1959 (Fairport Harbor Mine) and 1962 (Cleveland Mine), the salt produced in Ohio was obtained by artificial brining and, to a limited extent, by pumping of natural brines. This salt was processed either as vacuum-pan salt or as feed brine for use in chlorocaustic and soda ash chemical plants. The fine grain size of the vacuum-pan salt made it unsuited for use in such varied operations as tanning of hides, snow and ice control, refrigerator-car icing, and operation of lixiviators and ice cream freezers. The opening of the Cleveland and Fairport Harbor Mines not only made coarse-grained salt available locally at reduced cost, but also created a marketable surplus for shipments to other states and countries.

OHIO SALT DEPOSITS

The Ohio salt deposits consist of some 20 or more discrete zones, which are 2 to 50 feet thick and are interbedded with dolostone, anhydrite, and shale of the Upper Silurian Salina Group. The Salina rocks constitute a major stratigraphic interval in parts of Michigan, Ontario, New York, Pennsylvania, and West Virginia, as well as in Ohio (fig. 2). Within Ohio those portions of the Salina Group which are salt bearing underlie more than 20 counties in the eastern third of the state (fig. 3). The regional dip of the rocks is southeasterly from roughly 30 feet per mile in the northwest to about 80 feet per mile in the southeast. Depth to the top of the salt ranges from slightly less than 1,400 feet in Lorain County to more than 6,600 feet in Monroe County (fig. 3).

On the basis of lithology and geophysical logs, the stratigraphy of the Salina Group is readily divisible into 10 or more units (fig. 4), to which letter desig-

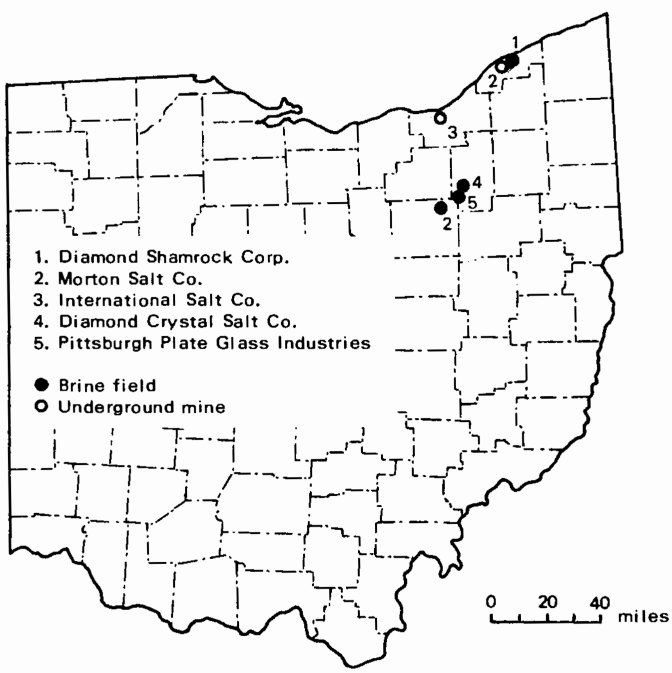


FIGURE 1.—Location map showing active salt-extraction operations in Ohio.

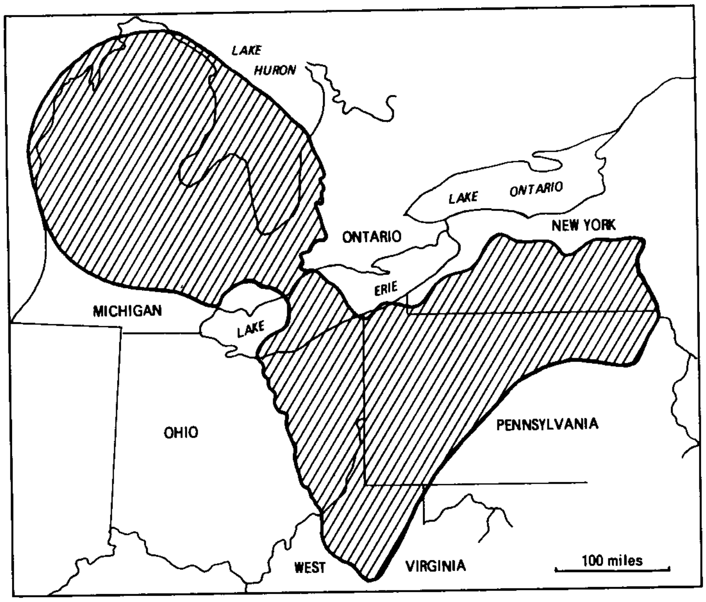


FIGURE 2.–Regional distribution of salt-bearing Salina Group (modified from Clifford, 1973).

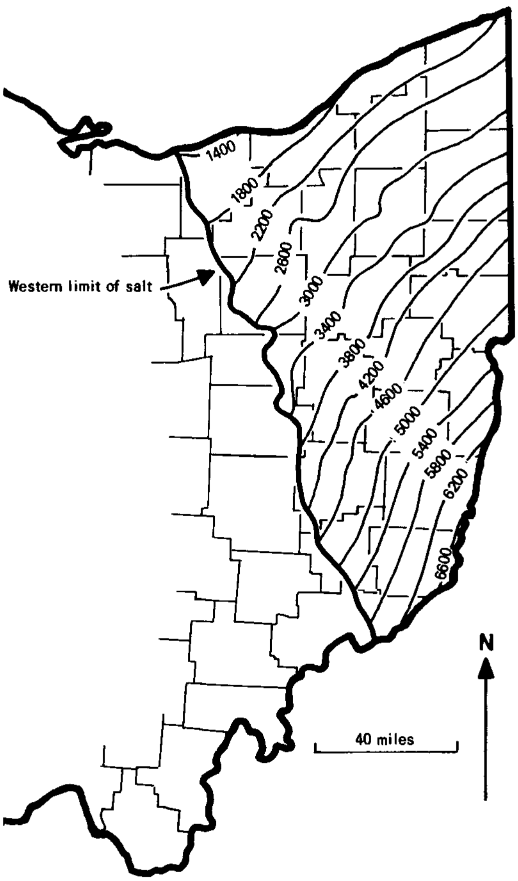


FIGURE 3.–Depth to top of Salina salt in Ohio (modified from Clifford, 1973).

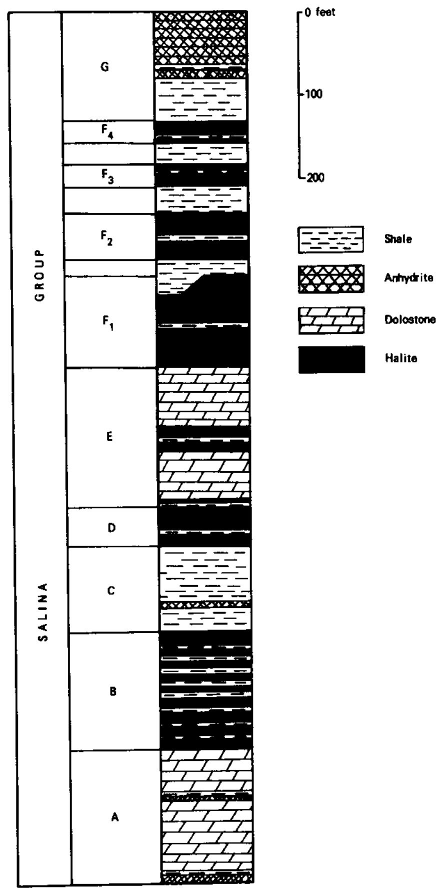


FIGURE 4.–Composite section of the Salina Group in Ohio (modified from Clifford, 1973).

nations have been given (Landes, 1945; Ulteig, 1964; Jacoby, 1969). The greatest concentrations of salt are found in four zones which correspond essentially to units B, D, F_1, and F_2. The various units can be traced in the subsurface from Michigan to eastern New York (Ulteig, 1964; Jacoby, 1969; Rickard, 1969). Individual salt beds themselves demonstrate remarkable lateral persistence. Clifford (1973), using close well control, was able to trace several salt beds in Ohio over areas of 500 square miles and, using moderate control, over 5,000 square miles.

TOPOGRAPHIC MAPS

The route of this field trip may be followed on 10 U.S. Geological Survey 7½-minute topographic quadrangle maps:

Kent	Chagrin Falls
Aurora	Mayfield Heights
Twinsburg	East Cleveland
Northfield	Cleveland North
Shaker Heights	Cleveland South (SALT MINE STOP)

ROAD LOG

Mileage			
Kent quadrangle			
	0.0	0.0	Starting point - Kent State University Student Center. *Turn right* (northwest) on Summit St.
	1.0	1.0	Cross Cuyahoga River. *Turn right* (north) on S. River St.
	1.2	0.2	Intersection with W. Main St. (Ohio Rte. 59). Continue straight (north).
	1.6	0.4	Continue straight (north) on N. Mantua St. (Ohio Rte. 43).
	7.7	6.1	*Turn left* (west) on Ohio Rte. 14.
Aurora quadrangle			
Twinsburg quadrangle			
Northfield quadrangle			
	19.8	12.1	Continue straight (northwest) on I-271.
Shaker Heights quadrangle			
Chagrin Falls quadrangle			
Mayfield Heights quadrangle			
	37.3	17.5	Exit I-271 onto I-90 (West - Cleveland).
East Cleveland quadrangle			
Cleveland North quadrangle			
	52.3	15.0	*Bear right* (west) on Ohio Rte. 2 (Downtown Cleveland).
Cleveland South quadrangle			
	54.9	2.6	*Bear left* (south) and take W. 28th St. exit ramp.
	55.0	0.1	*Turn right* (north) on W. 28th St. and then *immediately right* (east) on Washington Ave.
	55.1	0.1	*Turn right* (south) on W. 25th St. and then *immediately left* (northeast) on Main Ave.
	55.4	0.3	*Turn left* (northwest) on Elm St. and continue toward lift bridge.
	55.7	0.3	*Turn right* (north) on River St. and cross lift bridge.
	55.8	0.1	*Bear left* (west) on private road to International Salt Company.
	56.1	0.3	*Turn right* (north) into visitors' parking lot.

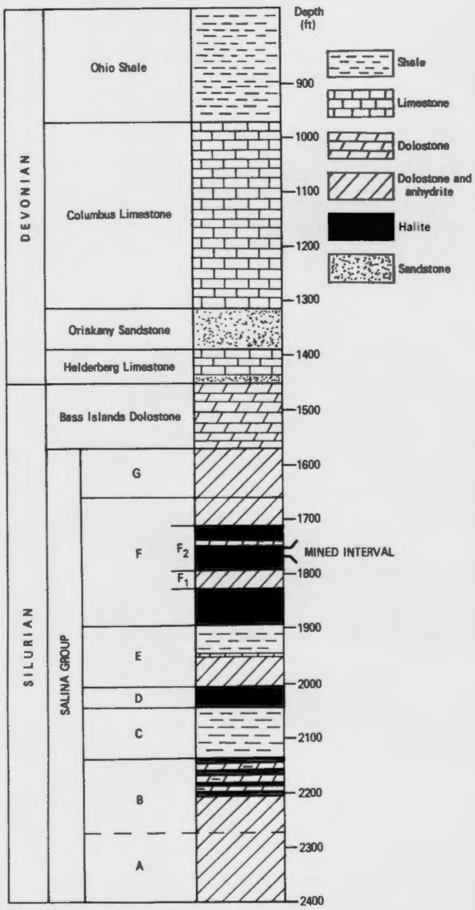


FIGURE 5.—Stratigraphic section at the Cleveland Mine (after Clifford, 1973).

FIGURE 6.—Bedded halite, anhydrite, and dolostone; asymmetrical folds. Portion of standing figure for scale.

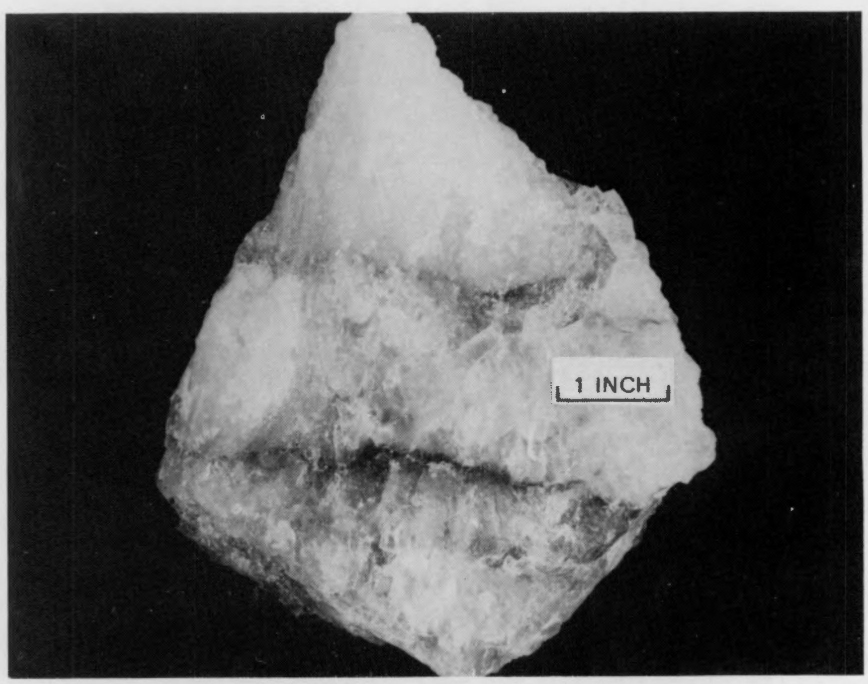


FIGURE 7.—Specimen showing thin anhydrite laminae (two dark zones) and beds of coarse crystalline halite.

THE CLEVELAND MINE

In the Cleveland Mine, salt is extracted at a depth of 1,760 feet from strata 18 to 22 feet thick within unit F_2 (fig. 5), the uppermost of the four salt-rich zones of the Salina Group.

Stratigraphy

The mined strata consist primarily of bedded halite (95 percent of the total section) which contains relatively thin layers of anhydrite and thicker layers of dolostone (fig. 6). Commonly 2 inches to 1 foot thick, the halite beds are aggregates of colorless, white, or gray medium to coarse interlocking equant grains, which exhibit prominent cubic cleavage (fig. 7). The anhydrite occurs as numerous locally discontinuous layers (⅛ inch to 2 inches thick) of very fine-grained light- to medium-brown material (fig. 7). The fine-grained deep-brown dolostone is present in regular beds and scattered patches. The dolostone layers are typically 1 to 3 inches thick and contain very thin

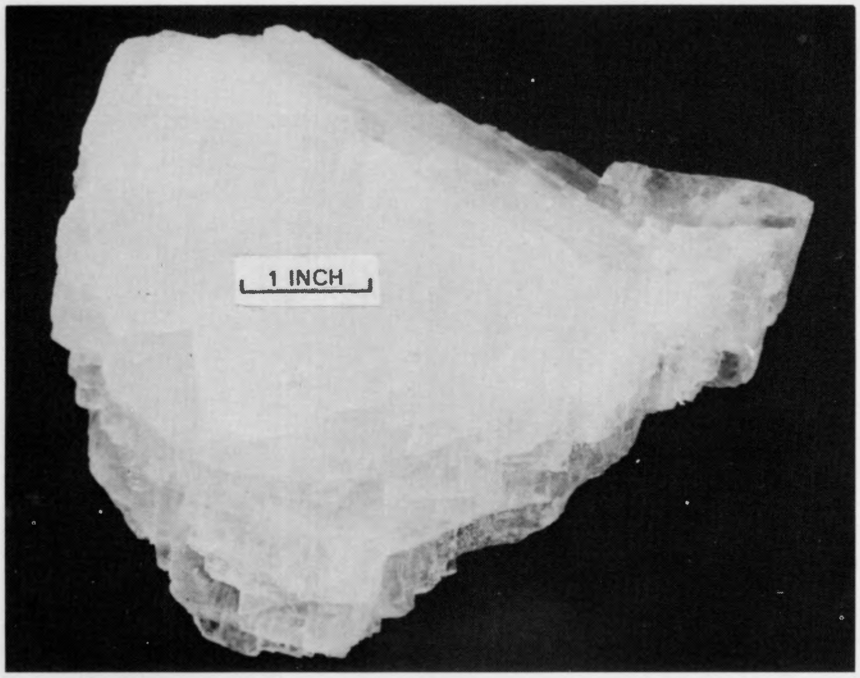


FIGURE 8.—Specimen of very coarse-grained clear halite from a concordant lens.

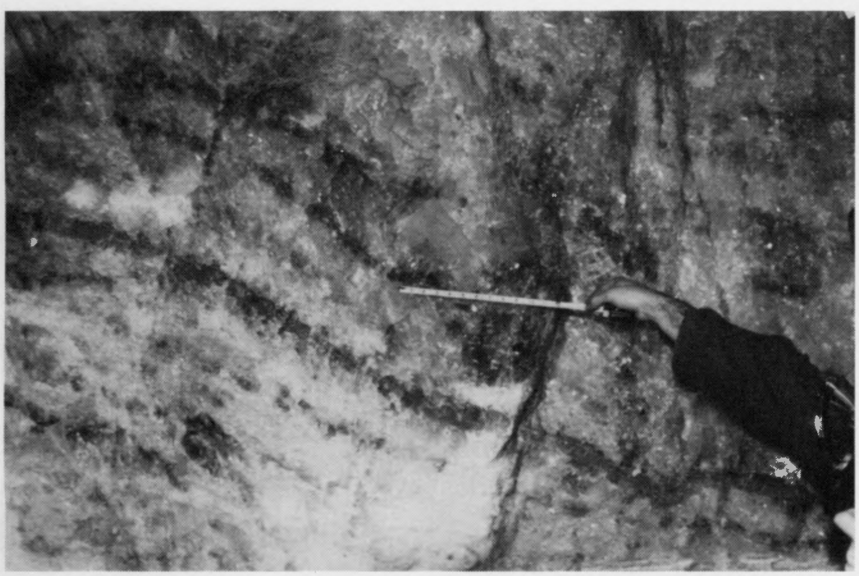


FIGURE 9.—Discordant clear halite body (extending from left end of steel tape to top of photo) containing a large cube of halite (just above left end of tape).

lenses and patches of halite.

Detailed studies of correlative units of "laminated" salt in the Salina Group of New York (Treesh and Friedman, in press) indicate a water-insoluble residue content of 2 to 15 weight percent. In addition to anhydrite and dolomite, the insolubles include quartz, clay, chlorite, calcite, feldspar, and talc.

Associated locally with the common bedded salt is some very coarse-grained extremely clear crystalline halite (fig. 8) which occurs as concordant and discordant bodies up to 6 feet in maximum dimension. Individual cubic crystals of this halite are as much as 6 inches on the edge (fig. 9). Fluid inclusions ⅛ to ¼ inch in diameter are commonly visible in this material. Both the concordant and discordant masses lack internal structure, although the concordant bodies may contain continuous or detached extensions of dolostone or anhydrite beds present on either side of the bodies (fig. 10). Although figure 10 shows little or no evidence of displacement above or below the crystalline lens, other concordant bodies appear to have grown at the expense of the adjacent sediments by disrupting and displacing the beds (fig. 11). Some of the discordant bodies displace the host, whereas some appear to have filled open spaces (fig. 9). Clearly these bodies formed after deposition and after at least partial lithification of the main bedded halite deposits; this sequence is indicated by the very coarse grain size,

FIGURE 10.—Concordant clear halite lens in sharp contact with thin dolostone layer below, but gradational with bedded halite above and laterally. Note presence of parts of several anhydritic beds with the mass.

FIGURE 11.—Concordant displacive lens of clear halite. Note disruption and contortion of beds above and below the lens.

great purity, and lack of bedding of the discordant bodies, as well as by their locally displacive and transgressive relationships with the host. Presumably the bodies were localized by solution channels in the bedded halite (Jacoby, 1969; Dellwig and Evans, 1969).

Structure

Although the bedding is essentially horizontal throughout the area, there are numerous places where small-scale deformation of the beds has occurred. These deformational features include folds, fractures, and faults.

The folds are characteristically asymmetrical and of limited amplitude (less than 6 inches) and wavelength (less than 1 foot), as shown in figure 6. Locally folds may be overturned, recumbent, and/or broken into separate segments (fig. 6). The folds are characteristically confined to selected strata within the mined interval, intervening beds showing little or no evidence of folding. Figure 12 gives some idea of the larger scale undulation of the beds.

Fractures are represented in the mined section by cracks in the competent dolostone beds. In all cases these have been filled by flowage of adjacent salt into the openings. The overall relationships are suggestive of boudinage, common in metamorphic rocks.

Some evidence of faulting is present in the mine. Faults of limited displacement (measured in inches) are represented by rare grabenlike features (figs. 13 and 14). Small-scale normal faults and one rather significant normal fault have been reported by Jacoby (1970). The major fault, possessing a vertical displacement of some 47 feet (fig. 15), has altered the original plans for development of the mine. Associated with this fault are subsidiary faults which suggest the presence of graben structures and en echelon step faulting.

Mining methods

Since the commencement of operation in 1962, some 600 acres have been developed in the Cleveland Mine. The workings extend both northerly and westerly under Lake Erie (fig. 16). Present mining is entirely under the lake, roughly one mile offshore. The mine is served by production and service shafts, each 16 feet in diameter. The salt is mined by the room-and-pillar method (fig. 17), with approximately 50 percent of the salt retained as pillars, typically 80 feet on a side. Rooms are 45 feet wide, 18 to 22 feet high, and 120 feet long.

At the working face the salt is undercut about 12 feet back, and 60 holes are drilled for blasting with ammonium nitrate. After blasting, the salt is picked up by 8-ton and 16-ton end loaders and trucked to primary crushers. Conveyor belts transport it for further crushing, screening, inspection, and storage. All operations, including storage of some 30,000 tons, take place underground.

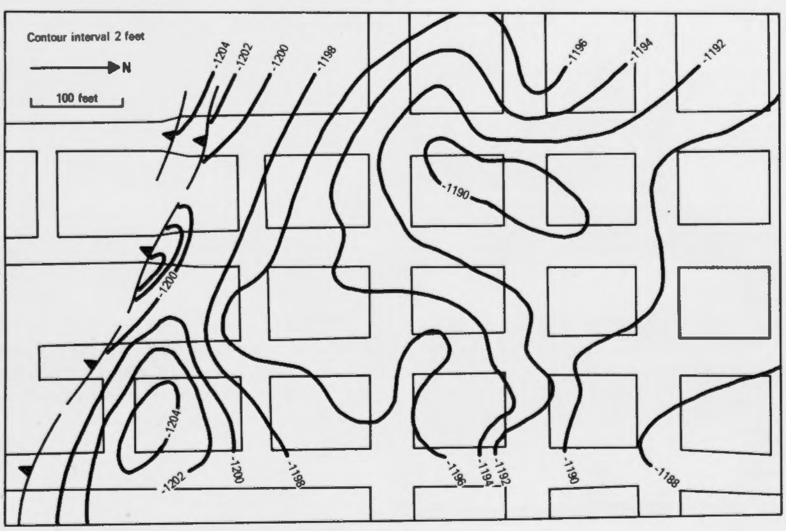


FIGURE 12.—Structural contour map drawn on a key horizon within the mined interval in mine headings 1-4 North, just north of the major fault. Contours abut several faults which are associated with the major fault, located slightly left of the figure.

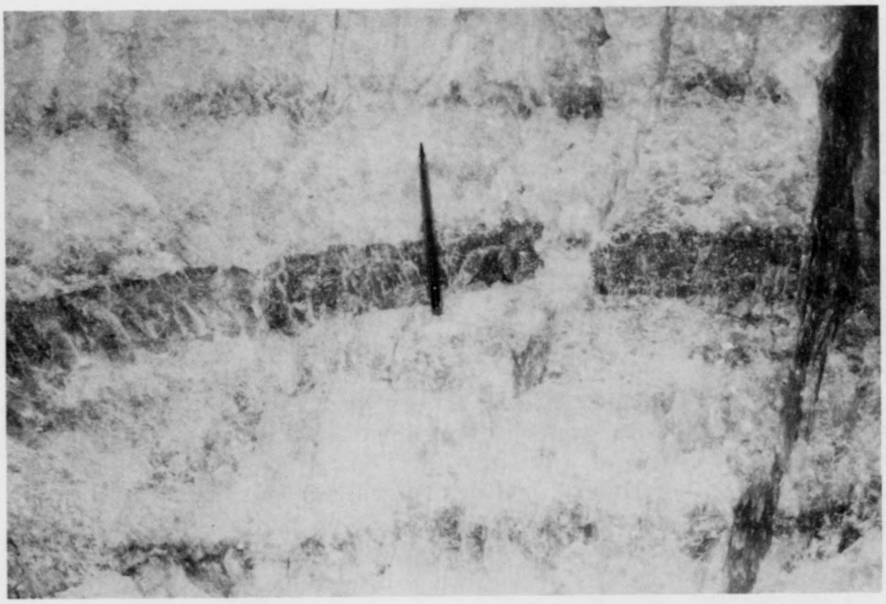
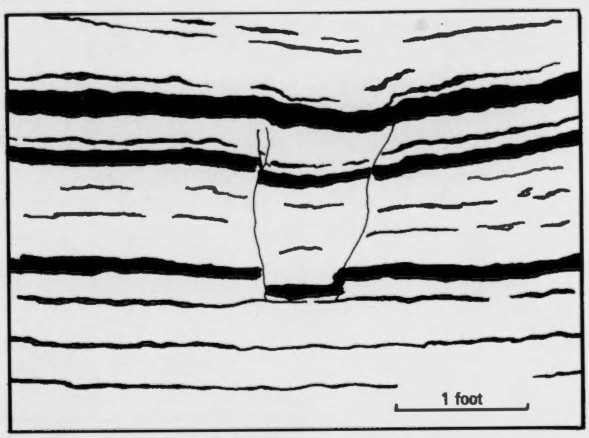


FIGURE 13.--Down-dropped segment (to right of pencil) of a dolostone bed.

FIGURE 14.--Sketch of grabenlike feature.



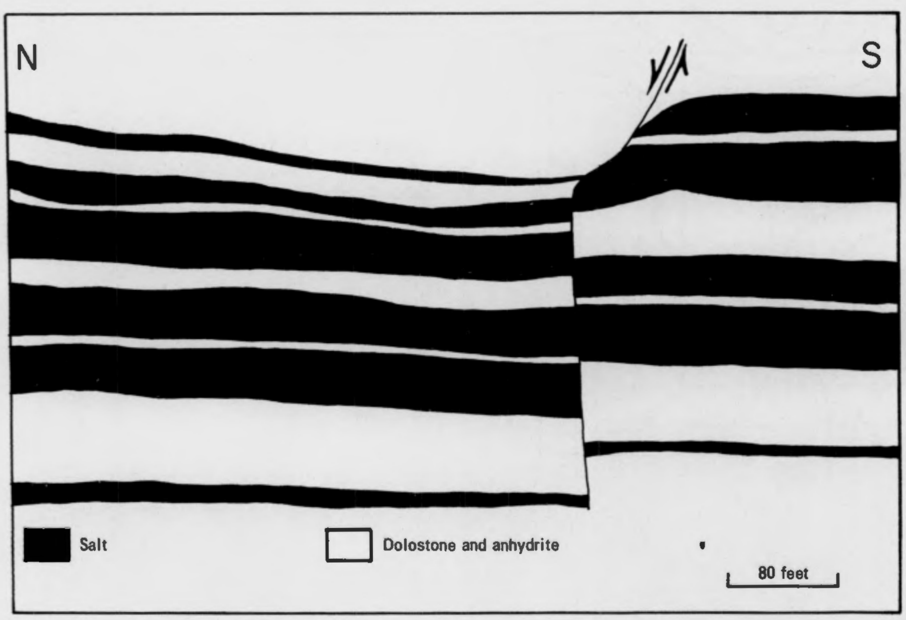


FIGURE 15.--Cross section showing displacement along the major normal fault in the area of mine heading 4 North. Interpretation is based on mine excavation and drill-hole data.

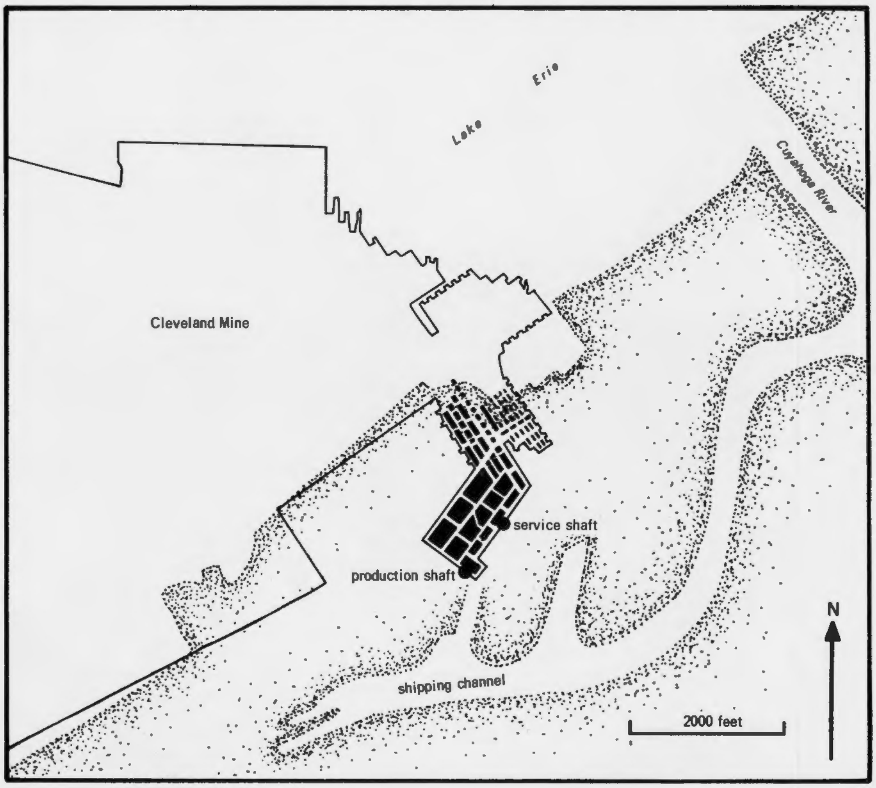


FIGURE 16.–Outline of the Cleveland Mine, showing a portion of the underground workings.

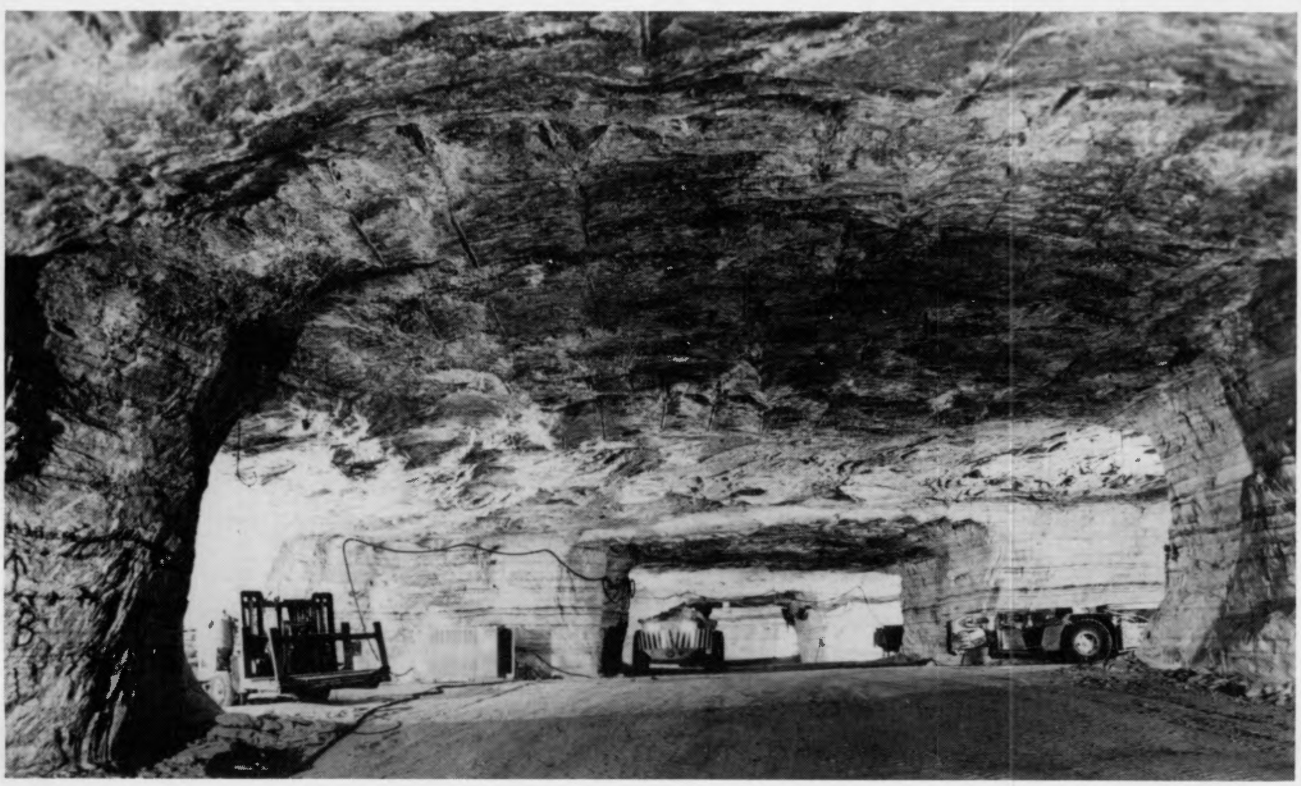


FIGURE 17.–View of a portion of the underground workings at the Cleveland Mine.

Daily production in the mine is about 8,000 tons. The mill capacity is 700 tons per hour. Roughly 35 percent of the salt is used for snow and ice control; the remainder is for table salt and for industrial and agricultural uses.

The underground tour

The underground tour will focus on the more salient aspects of the geology, mining, and processing of the salt. Stops will be made to examine general stratigraphy of the mined interval, bodies of coarsely crystalline halite, evidence for the major normal fault, and small-scale folds and faults. Additional stops will illustrate drilling and recovery methods and will trace the flow of salt through the mine.

ORIGIN OF THE SALT DEPOSITS

Relative to the origin of the deposits, three current models of evaporite deposition provide for concentration past the solubility product of a given salt or for the complete evaporation of sea water. The popular barred-basin model (fig. 18A) requires a body of sea water restricted from the open sea by a shallow shelf or other submerged barrier; the basin might be shallow (Scruton, 1953) or it might be deep, comparable to that of the Mediterranean Sea (Schmalz, 1969). A second model proposes an epeiric sea associated with an extensive gentle shelf (fig. 18B) that inhibits circulation with the open sea (Richter-Bernburg, 1955, 1968; Harris, 1973; Irwin, 1965). A recently proposed third view applies the sabkha or supratidal model (fig. 18C)

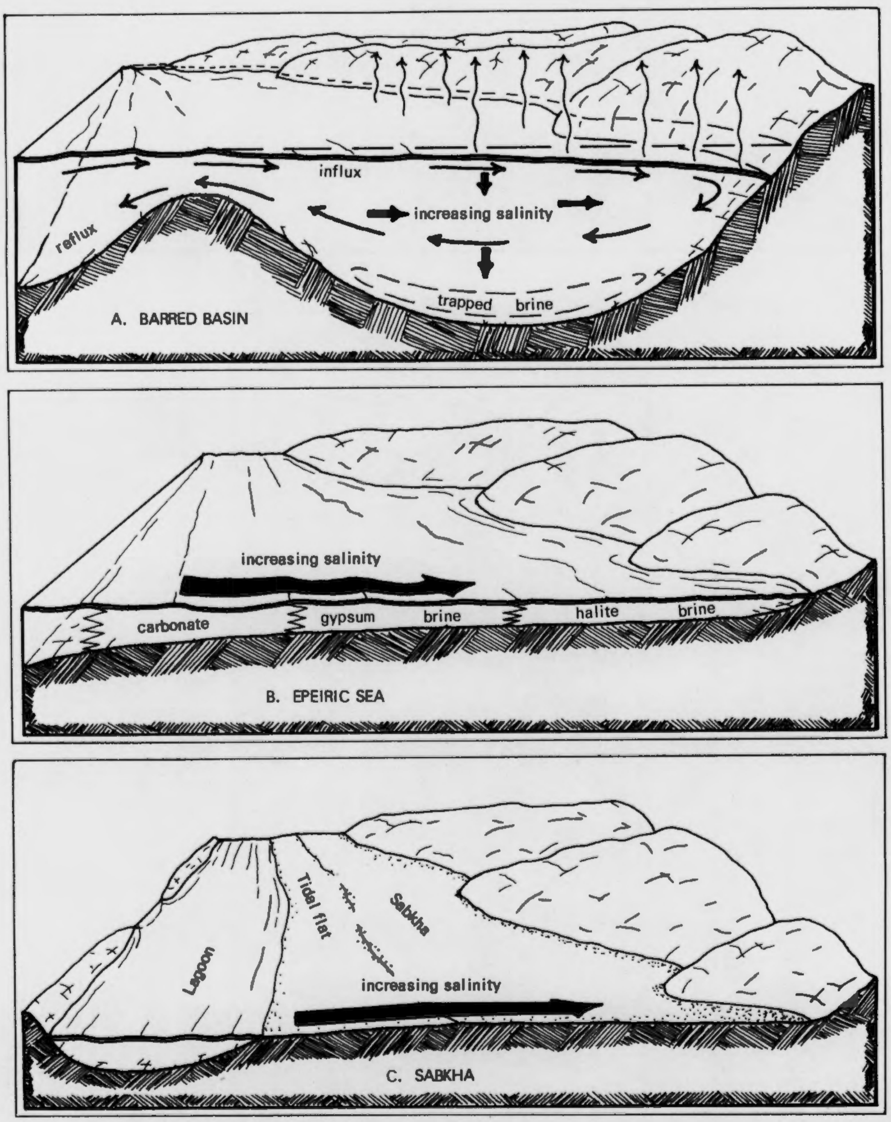


FIGURE 18.—Depositional models for the formation of salt deposits.

to halite deposition (Friedman, 1972; Treesh and Friedman, in press). Because most recent explanations of Salina salt deposition have emphasized the barred-basin and sabkha models, these will be outlined briefly and discussed as they relate to the Salina evaporites.

The barred basin is separated from the open sea by some sort of generally submergent barrier which restricts ocean-basin circulation. Evaporation in the basin must exceed input via precipitation and runoff, thereby implying an arid climate. Ultimately such a condition leads to hypersalinity in the basin. As the surface waters become more dense they sink to the bottom of the basin, and brine layers develop. When the solubility product of a given mineral is exceeded, the mineral will precipitate. Waters will become increasingly saline through evaporation as distance from the marine source increases; thus landward waters become more concentrated with salts and more dense. Relatively fresh marine waters, being less dense than the hypersaline basin water, flow from the sea into the basin to replenish water lost by evaporation. This generates a countercurrent which, if there is sufficient water depth over the barrier (a function of sea level), refluxes denser water out of the basin (fig. 18A). The balance struck between marine influx and reflux, as well as between evaporation and fresh-water input, controls the concentration achieved by the brine and thus the nature of the evaporite mineral deposited. Hence the mineral being precipitated can be held constant. This accounts for the observed difference between the relatively great thickness of anhydrite in most evaporite sequences and the thickness that would be expected as a result of simple evaporation of sea water without reflux. Changes in brine balance account for vertical alterations of lithology, whereas horizontal salinity gradients and shallow circulation systems provide an explanation for the common lateral interfingering of facies in evaporite deposits. A major difference exists between the deep-water barred basin and the shallow-water barred basin. In the deep-water model the denser brine layers sink below the level of reflux currents and are trapped and stagnant at the bottom of the basin. In the shallow-water model the denser brines move out of the basin under reflux to a degree governed by the depth of water over the barrier. The more restricted the passage, the less reflux can be achieved. Reflux helps to explain why the full sequence of evaporite minerals is not seen in most evaporite deposits.

Clifford (1973) is the most recent author to apply the barred-basin concept to the Ohio salts. Because of the total thickness of this evaporite sequence, he favors the deep-barred-basin model. Clifford cites the widespread layer-cake geometry of the Salina Group as an argument for simultaneous deposition over a broad area. Further, he raises the point that the salt beds appear to lack lateral facies equivalents, *i.e.*, when salt was being deposited other types of sediment were not. This is based on the observation that the total thickness of the Salina Group minus the salt is essentially uniform. If the salt were not extensive and essentially geologically instantaneous over a broad area the associated non-salt-bearing rocks should vary in thickness. This conclusion was in agreement with the work of Evans (1950) and of Rickard (1969). Clifford observed also a case where the Salina beds drape with marked thinning over an underlying high (presumably a reef). Because thinning is most evident in the salts, the effect is to support the conclusion that the evaporites were precipitated as a rain of halite, hence their thinning over the topographic high. This is distinctly analogous to the A-2 and B salt thinning which takes place over the Marine City Niagaran reef of the Michigan basin (Jodry, 1969).

The geochemistry of bromide in evaporites is beyond the scope of this paper (the interested reader is referred to Schmalz, 1969; Kunasz, 1966; and Holser, 1966), but certain general aspects as they relate to the barred basin are worth mentioning. First, the bromide concentration of a salt is a function of the concentration of the parent brine. Thus salts precipitated from highly concentrated brines, occupying the deeper parts of the basin, would contain greater amounts of bromide than would salts precipitated from less dense brines at the shallow basin margins. Analyses of clear halite, presumably formed *in situ* on the basin floor, commonly reflect this difference (Kunasz, 1968). Likewise, salts precipitated from surface waters (hopper crystals, Dellwig, 1955) would contain less bromide than salts derived from deep-basin brines; Kunasz (1968) also found this to be true. Secondly, for a given salt of a single precipitation, salt precipitated later should contain greater amounts of bromide. Hence in a series of vertical samples from a single salt bed one would logically expect increasing bromide content higher in the bed. However, Kunasz (1966) and Matthews and Egleson (in press) have shown that the bromide values increase upward to a maximum at an intermediate position within the layer; above this position they decrease progressively. This trend is explained (Kunasz, 1966) as reflecting a "dry" episode, in which the brine became progressively concentrated, followed by a "wet" episode, in which the brine was diluted by meteoric waters which dissolved halite exposed during the "dry" episode and recycled it into the basin. While hypothetical, this explanation is nicely consistent with the barred-basin concept.

Further evidence, again largely from the Michigan basin, supports the deep-barred-basin interpretation. For example, Matthews and Egleson (in press) point to the relative absence of clastic rocks in the first three evaporite megacycles of the Michigan basin as evidence that the marginal areas were deep-water covered; they do suggest, however, that the upper Salina units appear to have been deposited in shallow water. Widespread isochronous laminations and alternations of clear and cloudy salt in the Michigan basin are cited by Dellwig and Evans (1969) as evidence of deep-water deposition, at least for the lower units of the Salina Group. For the New York-Pennsylvania basin and the Ohio basin, however, Dellwig and Evans propose a shallow-water origin, citing the presence of unconformities and the absence of laminations in halite of the Retsoff Mine in New York. Interpretations of salts deposited in shallow environments lead, inevitably, to a consideration of their precipitation under shallow-barred-basin, epeiric-sea, or sabkha conditions.

The more recently proposed sabkha model is not yet as elegantly developed with respect to salt as is the barred-basin model. The sabkha has been suggested as an alternative to the barred basin largely because no barred basin exists in which extensive evaporites are presently being developed. Friedman (1972) demonstrated that in the Red Sea, a classic example of a barred basin, no evaporite sulfate minerals are presently being deposited nor have any accumulated over the past 70,000 years. He explained this as due to bacterial degradation of sulfate minerals. This proposal is reinforced by the study of Neev (1964), who showed that, although gypsum is actively precipitating from the surface waters of the Dead Sea, none is accumulating on the bottom. Instead, low-magnesium calcite of replacement origin is developed on the floor of the Dead Sea basin. Friedman (1972) cites several other examples where gypsum is preserved only under the oxidizing conditions associated with basin margins and is decomposed under reducing conditions in the deeper portions of a basin. If evaporite sulfates cannot form under deep or stagnant basin conditions then an alternative shallow-water model must be proposed for sulfate and associated halite as well. Since the well-known sabkha model (Kinsman, 1966, 1969) explains appreciable degrees of gypsum deposition, it is a logical extension to apply it to halite accumulation. Simply put, the model proposes that halite originates either as a direct precipitate on a flooded sabkha or as a replacement product of preexisting sulfates which were deposited in a sabkha environment. Friedman (1972), in support of a replacement origin for halite, discusses several lines of evidence from numerous areas. The replacement mechanisms are speculative. A well-reasoned account of this aspect is given by Treesh and Friedman (in press). As evidence for a sabkha origin in the New York basin, these authors refer to desiccation cracks, sulfate nodules, halite crusts, flat-pebble conglomerates, abundant erosion surfaces, and algal stromatolites in the carbonate-sulfate rocks.

An interesting point to keep in mind is that most of the evidence pointing to a deep-barred-basin model for origin of salt is derived from studies of the Michigan basin, whereas the preponderance of evidence pointing to the shallow-water or sabkha model is drawn from the New York basin. The Ohio basin seems to have elements of both and deserves further study.

ACKNOWLEDGMENTS

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FIELD TRIP NO. 2

SEDIMENTARY ENVIRONMENTS OF THE LOWER PENNSYLVANIAN SHARON CONGLOMERATE NEAR AKRON, OHIO

by

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INTRODUCTION

The study of sedimentary environments has traditionally focused on ancient marine environments because the vast majority of sedimentary rock exposed around the world is of that origin. Although nonmarine environments have received less attention, in recent years fluvial environments, primarily those associated with meandering streams, have been studied more intensively because of their implication for petroleum exploration. When sequences of sedimentation are generalized, it becomes evident that certain fluvial sequences do not fit well into the model of normal meandering stream deposition. Very recent studies, within the past 10 years, have indicated the possibility that these deposits may have been formed in response to the low-discharge high-bed-load regime of braided stream channels.

On this field trip we will study the Lower Pennsylvanian Sharon Conglomerate and will observe sedimentary structures and textures that may well lead to the conclusion that the Sharon was deposited under braided stream conditions. Because this unit has been interpreted as of deltaic origin (deposited by meandering streams) as well as the result of braided stream deposition we will present both models and look at the evidence supporting each. Conclusions can be drawn individually by field trip participants.

Although the *raison d'etre* for this trip is the 1974 annual meeting of the North-Central Section of the Geological Society of America, the trip can be taken during almost any time of the year with little difficulty. Stops selected to demonstrate the nature of the Sharon Conglomerate are located in two parks (fig. 1) maintained by the Akron Metropolitan Park System, so that ready access, parking, and convenience facilities are always available.

TOPOGRAPHIC MAPS

The route of this field trip may be followed on five U.S. Geological Survey 7½-minute topographic quadrangle maps:

Kent
Hudson
Akron East (STOP 1)
Akron West
Peninsula (STOP 2)

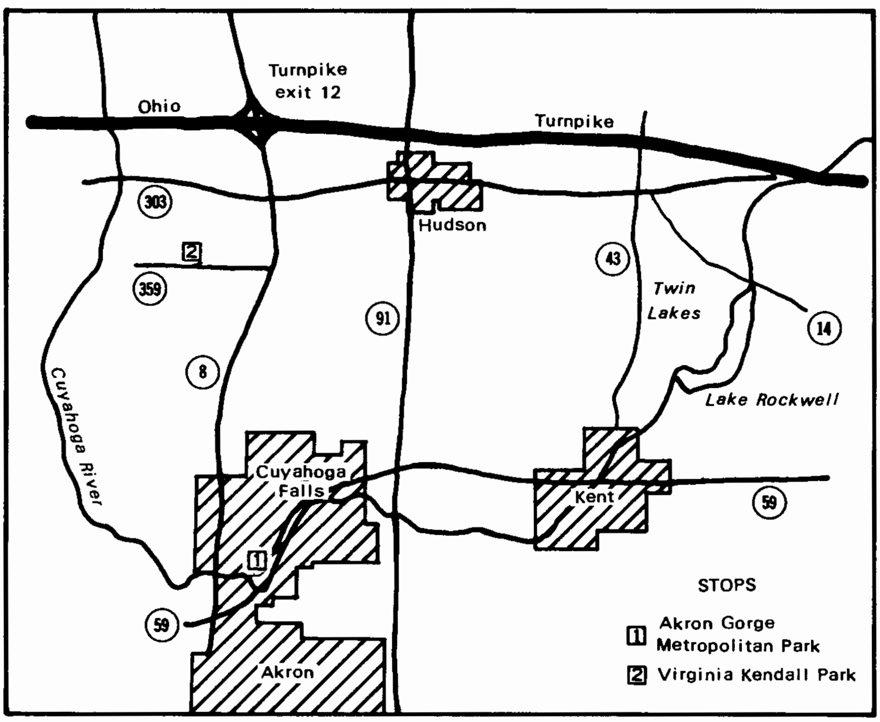


FIGURE 1.—Sketch map showing the locations of stops described in the field guide.

ROAD LOG

Quadrangle	*Mileage*		
	0		Intersection of Main and Water Sts. in downtown Kent. Proceed west on Ohio Rte. 59 (Main St.). The Cuyahoga River at this point is flowing south and cutting through the Sharon Conglomerate.
Kent quadrangle / *Hudson quadrangle*	1.0	1.0	Intersection of Main and Stow Sts. Continue west on Ohio Rte. 59.
	1.9	0.9	Enter Stow, Ohio, and continue west on Rte. 59.
	4.3	2.4	Intersection of Ohio Rtes. 59 and 91 (Darrow Rd.). Continue southwest on Rte. 59.
	5.8	1.5	Enter Cuyahoga Falls, Ohio, and continue southwest on Rte. 59.
	6.2	0.4	Cross fresh exposures of Sharon Formation as Rte. 59 becomes one-way. Continue southwest on Rte. 59.
	7.0	0.8	Intersection of Rte. 59 and Broad Blvd. Continue on Rte. 59.
Hudson quadrangle / *Akron East quadrangle*	8.0	1.0	Entrance to Gorge Metropolitan Park. *Turn in* and park. STOP 1.
	8.1	0.1	Return to Rte. 59 and proceed southwest across Cuyahoga River.
	8.2	0.1	Enter Akron, Ohio.
Akron East quadrangle / *Akron West quadrangle*	9.3	1.1	Junction of Ohio Rtes. 59 and 8. *Turn right* (north) on Rte. 8.
	10.2	0.9	Cross Cuyahoga River on "high bridge." Gorge Metropolitan Park extends up to the bridge on the right (east). Continue north on Rte. 8.
Akron West quadrangle / *Peninsula quadrangle*	11.8	1.6	Junction of Rte. 8 and Portage Trail. Continue north on Rte. 8.

Peninsula quadrangle / *Hudson quadrangle*			
	15.6	3.8	Junction of Ohio Rtes. 8 and 532. Tamsin Park on the left (west). Continue north on Rte. 8.
	16.6	1.0	Junction of Ohio Rtes. 8 and 359 (Kendall Park Rd.). Entrance to Virginia Kendall Park. *Turn left* (west) on Rte. 359.
Hudson quadrangle / *Peninsula quadrangle*			
	17.5	0.9	*Turn right* (north) on road marked "Ledges" and enter Virginia Kendall Park.
	17.8	0.3	Park in lot on the left. STOP 2.
	18.1	0.3	Return to junction of road marked "Ledges" and Ohio Rte. 359. *Turn left* (east) on Rte. 359.
Peninsula quadrangle / *Hudson quadrangle*			
	19.0	0.9	Junction of Rte. 359 and Rte. 8. *Turn left* (north) on Rte. 8.
	19.9	0.9	Junction of Ohio Rtes. 8 and 303. *Turn right* (east) on Rte. 303.
	21.4	1.5	Enter village of Hudson, Ohio. Continue east on Rte. 303.
	22.4	1.0	Junction of Rtes. 303 and 91. Continue east on Rte. 303.
Hudson quadrangle / *Kent quadrangle*			
	26.9	4.5	Junction of Ohio Rtes. 303 and 14. *Turn right* on Rtes. 303 and 14.
	27.1	0.2	Junction of Ohio Rtes. 303, 14, and 43. *Turn right* (south) on Rte. 43.
	29.5	2.4	Enter village of Twin Lakes and continue south on Rte. 43.
	32.1	2.6	Enter Kent, Ohio, on North Mantua St. (Rte. 43) and continue southwest.
	33.0	0.9	Rte. 43 becomes one-way. Continue southwest.
	33.3	0.3	Junction of Ohio Rtes. 43 and 59 (Main St.). *Turn left* (east) on Rte. 59.
	33.5	0.2	Intersection of Main and Water Sts. in downtown Kent.

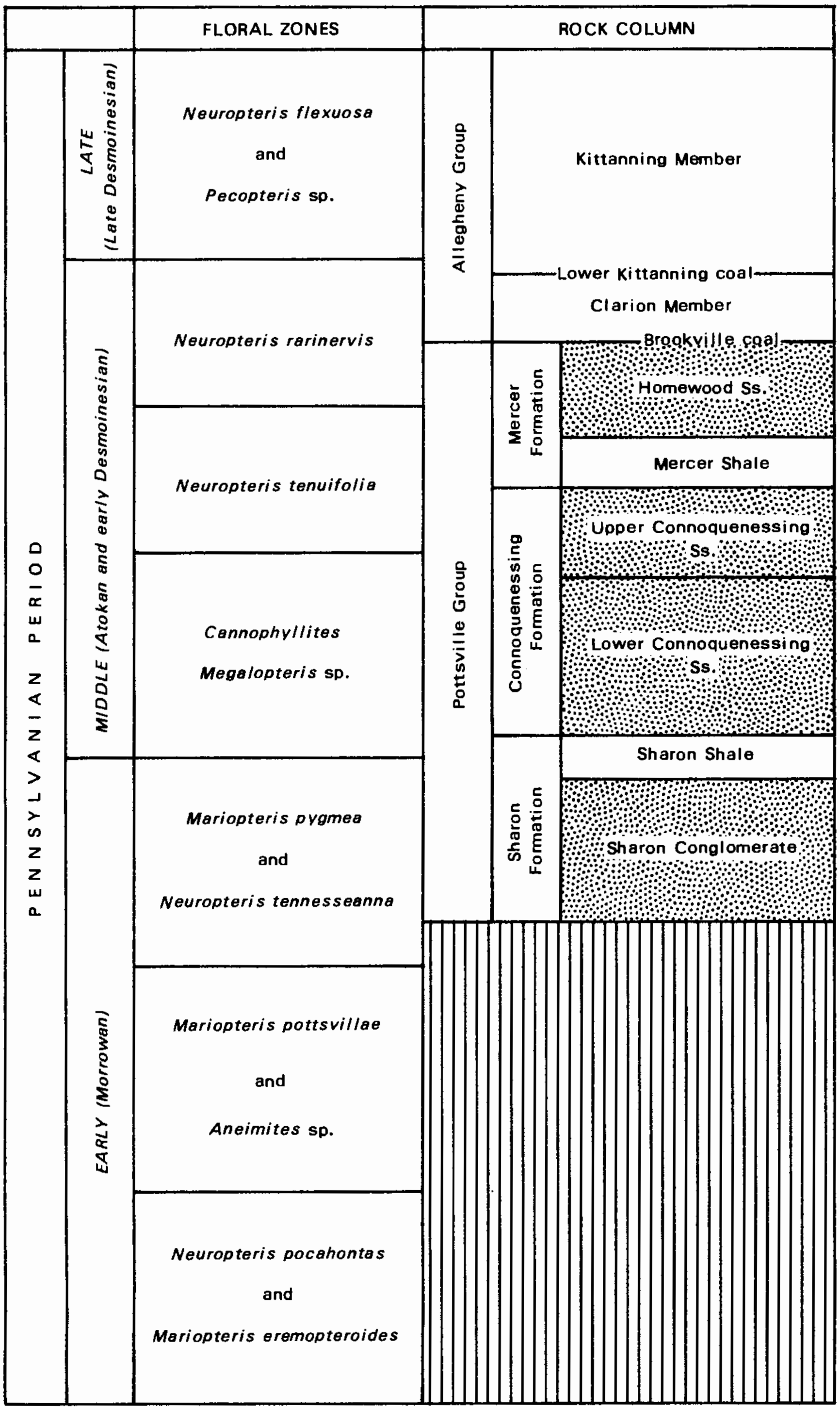


FIGURE 2.—Stratigraphic column showing age of Sharon Conglomerate as determined by floral zones (modified from Meckel, 1967, p. 228).

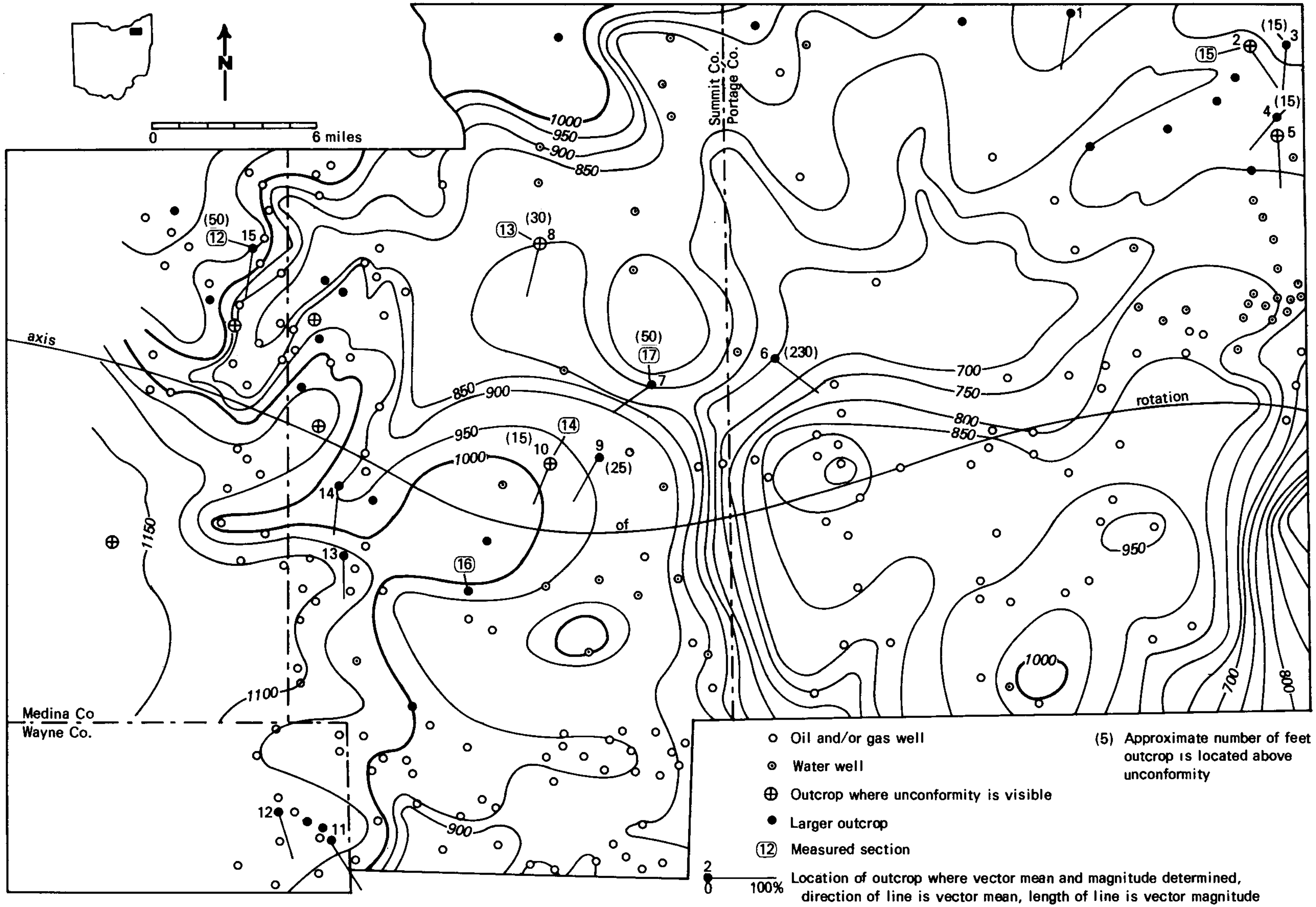


FIGURE 3.–Structural contour map on top of Mississippian strata. Locations of oil and gas wells, water wells, Sharon Conglomerate outcrops, vector means and magnitudes, measured sections, and axis of rotation used to correct elevations for regional dip are shown. The paleotopography shows a dendritic pattern of valleys trending generally south (Mrakovich, 1969b).

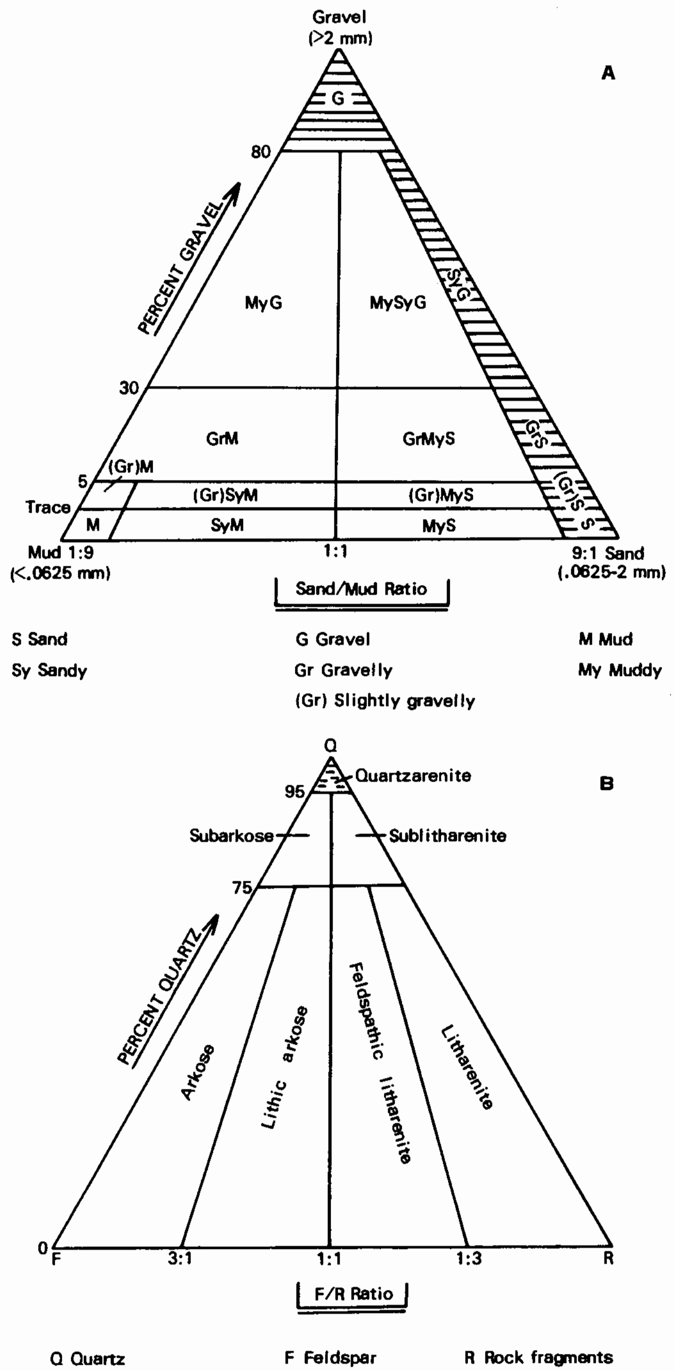


FIGURE 4.—Description of sediments from the Sharon formation in northeast Ohio. *A*, Ruled area shows size distribution in the Sharon according to Folk's (1968, p. 28) grain-size nomenclature (compiled from Bowen, 1953, p. 35-38) and from visual estimates at outcrops; *B*, ruled area shows mineralogy of Sharon according to Folk's (1968, p. 124) sandstone classification (compiled from Bowen, 1953, p. 39).

GENERAL SETTING OF THE SHARON CONGLOMERATE

The Sharon Conglomerate of northeastern Ohio (fig. 2) is the lowermost unit of the Pennsylvanian Pottsville Group. Although the unit is called the Sharon Conglomerate, sandstone is the more abundant rock type in this area. The Sharon is said to be a sheetlike deposit, but in Ohio it rests disconformably upon Mississippian strata of the Cuyahoga Group. The erosional surface appears to be maturely dissected, having, in some areas, relief up to 200 feet (fig. 3).

The Sharon Conglomerate consists of interbedded conglomerate, conglomeratic sandstone, and sandstone (fig. 4A). Rapid lateral and vertical transitions from conglomerate to sandstone are common. The material composing the Sharon is notable for its high silica content (fig. 4B); average figures are 97 percent silica for the sandstone and 98 percent silica for the conglomerate (Fuller, 1965). The conglomerates consist mostly of well-rounded quartz and quartzite pebbles. The average size of the components is 1.5 cm, but they may be as much as 17 cm in diameter (Meckel, 1967). The sandstones are medium-grained quartzarenite. A fresh sample is normally clean, white, and friable.

On the basis of geographic distribution, lithology, and regional stratigraphic relationships, Fuller (1955, 1965) and Bowen (1953) concluded that the Sharon was probably deposited as a delta or series of deltas. Mrakovich (1969a), however, performed a detailed study of the bedding types present in the unit and concluded that the Sharon represents a fluvial deposit, probably characterized by the low-discharge high-sediment load characteristic of modern braided stream complexes.

The purpose of this field trip will be to investigate the bedding types present in the Sharon Formation at two localities in northeastern Ohio, and to test the two theories against one another.

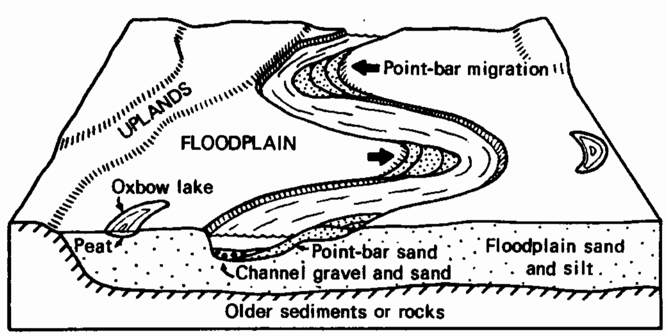


FIGURE 5.—Schematic illustration of a stream meandering across its valley fill and cutting its valley walls; note the channelward migration of the point-bar sands at the meander bends and the oxbow lakes in the cutoffs on the floodplain (from Coogan, 1969).

TWO MODELS OF SHARON DEPOSITION

The meandering stream model

When a stream flows around a meander bend in the river two things happen (fig. 5): (1) erosion takes place on the outside of the bend as the stream cuts into its earlier deposits and into the valley wall, and (2) sand is deposited on the inside of the bend in the form of subaqueous and subaerial bars known as point bars. In addition to such bars the major categories of stream deposits include sediments of the central channel of the river, and silts, clays, and peats deposited on the floodplain in settings such as oxbow lakes, created where a meander loop has been cut off.

Recent studies (Frazier and Osanik, 1961; Bernard and Major, 1963; Harms and Fahnestock, 1965; McKee, 1966; Visher, 1965; and others) of modern point-bar deposits provide the basis for distinguishing four major zones of bedding developed in the point bar as it migrates laterally into the river channel (fig. 6). These four zones–the basal massive or poorly bedded bed-load zone, the lower large-scale trough or festoon crossbedded zone, the middle horizontally laminated zone, and the upper small-scale ripple crossbedded zone–are generally overlain by clayey silty floodplain sediments deposited as levees or by bank overflow into swamps. The combined results of flume experiments and studies of modern rivers have shown that lateral and vertical sequences of deposits are related to the flow regime of the river and that an idealized vertical sequence of bedding types and lithology can be constructed as a model of fluvial deposition. An illustration of this model (fig. 6B) shows that the basal channel of the older rocks is unconformably overlain by the coarsest fluvial sediment, commonly pebbles or coarse sand carried as bed load; grain size decreases upward to clay or even sediment-free peat at the top.

The braided stream model

Braided streams are less well understood than meandering ones; literature on Recent braided river deposits has just lately begun to appear in scientific journals. Apparently many of the same physical processes are in effect in both types of rivers, as one might expect, but the resultant deposit appears different owing to difference in the predominant forces at work as the sediment is deposited. The tentative model presented here is derived from a study of the literature and of the Sharon Conglomerate itself in terms of physical processes interpreted from bedding types and the significance of these types as understood from flume studies.

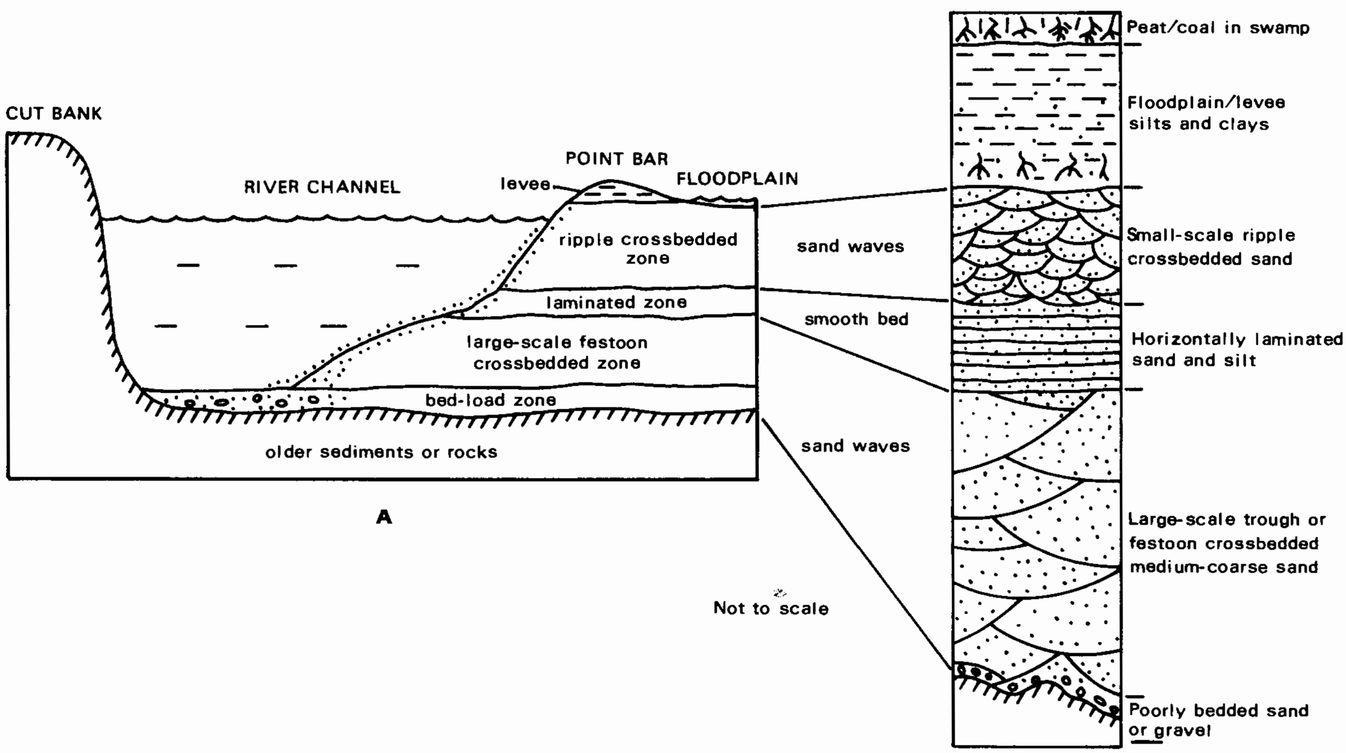


FIGURE 6.—Idealized vertical and lateral sequence of bedding types in a point bar and associated deposits: *A*, cross section of stream showing the major zones of bedding; *B*, detailed vertical sequence of bedding types (from Coogan, 1969).

An idealized vertical sequence of a braided stream deposit representing one complete flood cycle starts at low-water discharge, when the braided channels are the only ones functioning. The sequence continues to high-water discharge, when the entire channel and all the transverse bars in the river (fig. 7) are covered with shallow water, and ends with a return to low-water discharge, with the braided channels again being the only ones functioning.

Assuming uniform and constant changes in flow velocity, a complete vertical sequence from bottom to top for one flood cycle should be similar to that shown in figure 8.

This idealized sequence assumes perfect aggradation and a peak discharge in the upper flow regime. Whether or not the sequence is preserved depends on the amount of scour and erosion that occurs during and between floods. Grain-size analysis could provide supportive evidence for the model outlined above; grain size increased from the lower trough-crossbedded unit to the thick horizontally bedded unit and then decreased to the upper trough-crossbedded unit.

The sequence need not be characterized by changes in grain size, however, when all the bed load can be transported in the lower flow regime; in these circumstances sand is able to change through the complete series of bed forms from the lower to the upper flow regime (Simons *et al.*, 1965). If this were the case for the sandstones of the Sharon Conglomerate, that is, if the sandstones do represent a vertically aggraded deposit where gravity sorting could not operate, the absence of vertical textural variations could be a criterion for distinguishing wide shallow-river deposits—those in which all the bed load could be transported in the lower flow regime—from point bars, which have been well documented in reports (Visher, 1965, 1963; Klein, 1965; Bernard and Major, 1963) showing that a fining-upward sequence is characteristic.

The longitudinal bars described by Ore (1964), Leopold and Wolman (1957), and Smith (1970) are not included in the idealized vertical sequence because such bars do not so clearly appear to have their origin as bed forms related to regular flow regimes, but instead are deposits resulting from local stream incompetencies caused by channel obstructions and irregularities. This appears to be the case especially in the reach of the river characterized by transverse bars. Some of the planar-bedded gravel deposits in the Sharon between planar-bedded sands and some of the poorly sorted channel gravels may be longitudinal bars.

In a study of the South Platte River and the Silurian Tuscarora Formation of Pennsylvania, Smith (1970) observed that the downstream decrease in mean grain size and increase in sorting is accompanied by replace-

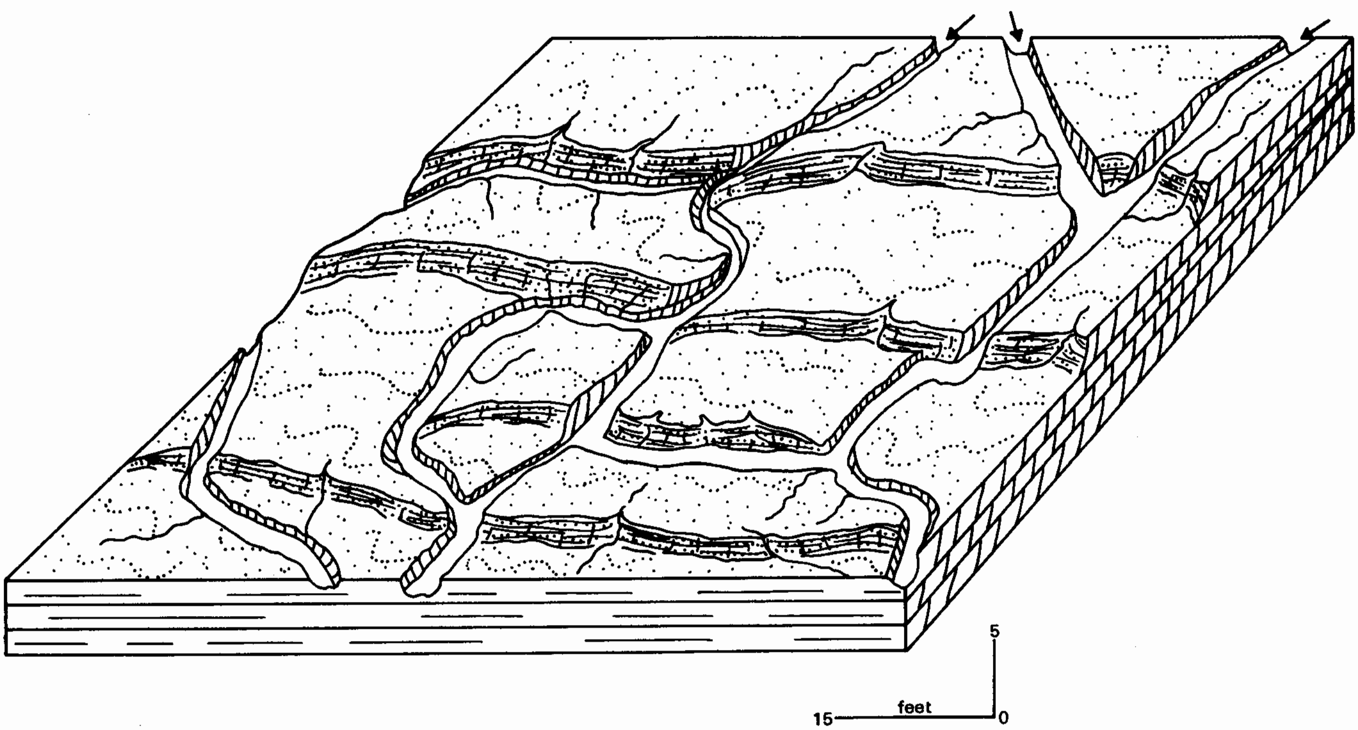


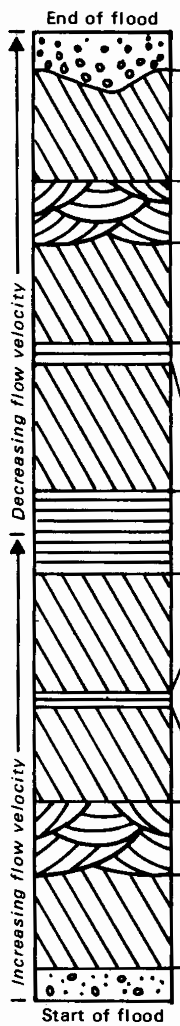
FIGURE 7.—Detailed illustration of part of a braided stream channel. Dunelike features are large tabular transverse bars by which bed-load transport takes place mainly during periods of high discharge (Ore, 1964, p. 3; Sundborg, 1956, p. 207). Braided channels develop when discharge decreases and bars emerge from the river (Ore, 1964, p. 3). Migrating transverse bars shown here are forming omicron (planar) cross-stratification. Superposed on bar tops are dune and ripple bed forms which, when preserved, would form pi and nu (trough) cross-stratification. Arrows indicate direction of flow.

ment of predominant longitudinal bars by transverse bars (fig. 9). This change is accompanied by decrease in bed relief. In addition the relative proportions of internal stratification change downstream. Longitudinal bars mainly display crude horizontal stratification in their coarse portions, with varying amounts of trough and planar cross-stratification toward their finer downstream margins. Transverse bars contain little horizontal stratification and are composed mainly of planar cross-strata near the downstream margins and trough cross-strata farther upstream. Smith observed that the ratio of planar cross-stratification to horizontal stratification increases downstream and that this may be a unique relationship for braided stream deposits. Unlike deposition and erosion in the meandering stream model, braided stream deposition and erosion occur simultaneously on a large scale, and it cannot be predicted with certainty how regular or irregular the preserved bedding surfaces will be. Consequently, the hypothetical model (fig. 8) is suggested as a point of reference for comparison with outcrops rather than as a predictive tool, as the meandering model (figs. 5, 6) can be.

STRATIFICATION IN THE SHARON CONGLOMERATE

Bedding types and terminology

The terminology and classification of bedding



DESCRIPTION	INTERPRETATION
Small cross-cutting channel	Part of a braided channel system transecting a transverse bar at low discharge
Planar-crossbedded set	A transverse bar deposit exposed during final stages of flood cycle
Trough-crossbedded set	Sands transported as dunes or ripples in the lower flow regime over the bar tops while bars were still covered by falling flood waters
Planar-crossbedded set	A transverse bar deposit that moved as dunes and ripples formed on the bar top and deposited on the downstream slope
Horizontally bedded set	Sands transported over bar tops as plane bed flow of upper flow regime
Planar-crossbedded set	A transverse bar deposit that moved as sands transported over bar top in plane bed flow of upper flow regime and deposited on downstream slope during decreasing discharge
Horizontally bedded set	Bed load of entire river channel moved in plane bed flow of upper flow regime at peak discharge
Planar-crossbedded set	A transverse bar deposit that moved as sands transported in plane bed flow over bar top and deposited on downstream side
Horizontally bedded set	Sands transported over bar tops in plane bed flow of upper flow regime
Planar-crossbedded set	A transverse bar deposit that moved as dunes and ripples formed on the bar tops and deposited on the downstream slopes
Trough-crossbedded set	Sands transported as dunes or ripples in the lower flow regime over the bar tops as bars become submerged during first periods of high discharge
Planar-crossbedded set	A transverse bar deposit which was exposed at beginning of increasing discharge
Small cross-cutting channel	Part of a braided channel system transecting a transverse bar at low discharge

FIGURE 8.—Hypothetical idealized braided river sequence of one complete flood cycle; perfect aggradation and uniformly increasing and decreasing flow velocities are assumed (compiled from Ore, 1964, Sundborg, 1956, and Simons *et al.*, 1965).

types (fig. 10) used here follows Allen (1963) to some extent because his classification sufficiently describes the different bedding aspects of the Sharon Conglomerate.

Of the two types of crossbedding occurring in the Sharon planar (omicron) crossbedding is the most abundant and dominates the sandstones, whereas the channel conglomerates exhibit a greater abundance of trough (pi) crossbedding and horizontal and massive bedding. Other types of crossbedding have been identified in the Sharon but are not commonly seen. For example small-scale (nu) trough crossbedding can be observed

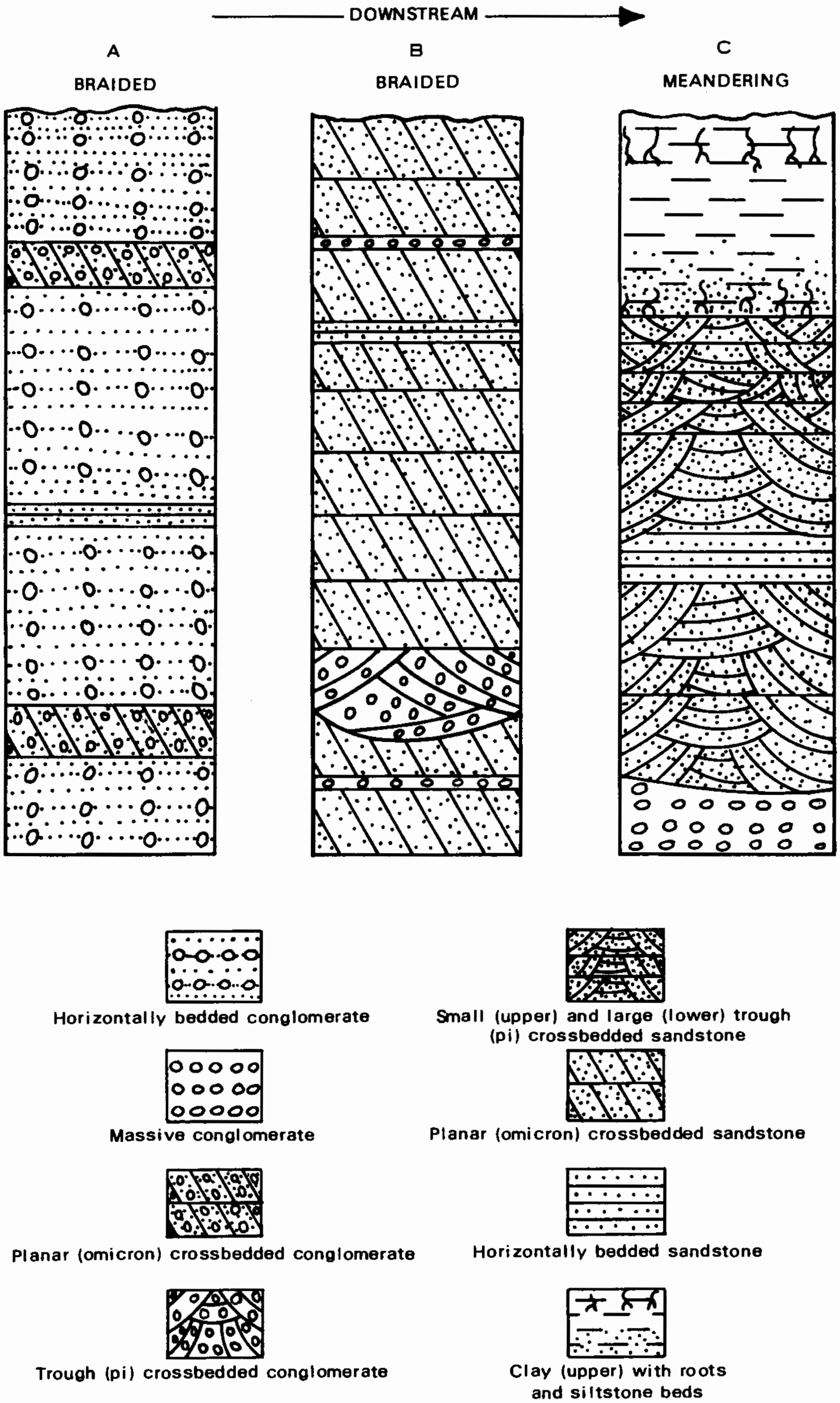


FIGURE 9.—Hypothetical sketch of rock sequences showing the predominant bedding types in a stream deposit which changes from *A*, a braided stream with mainly coarse longitudinal bars to *B*, one with sandy transverse bars to *C*, a meandering stream (compiled from Smith, 1970).

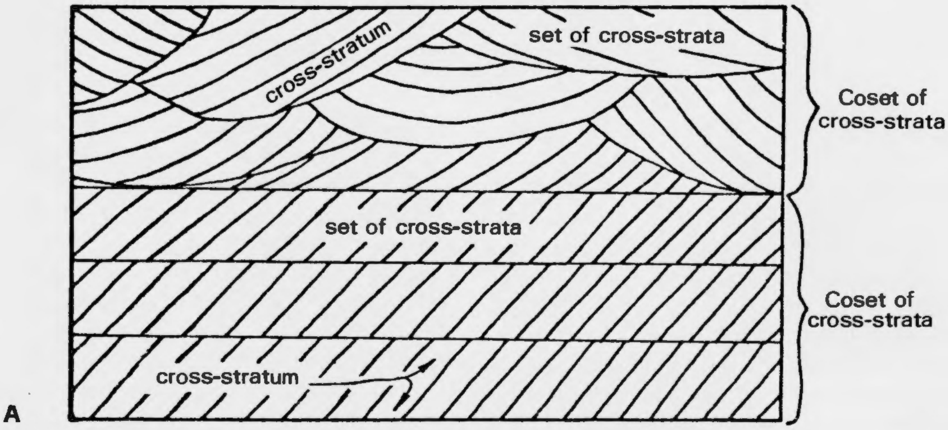
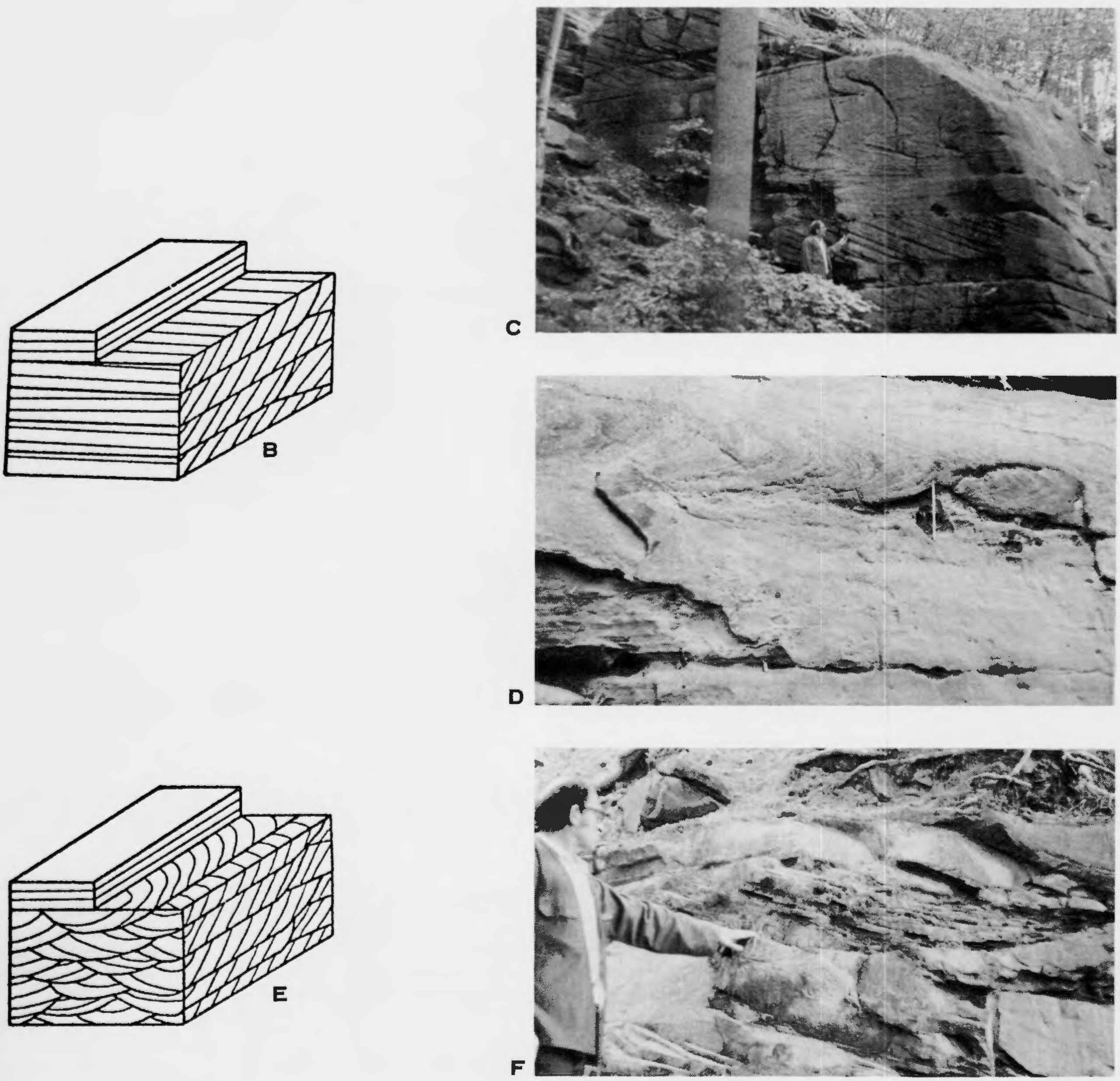


FIGURE 10.—Cross-stratification terminology: *A*, illustration of bedding terminology for cross-strata, sets, and cosets of cross-stratified rocks (after Allen, 1963, p. 95); *B*, omicron cross-stratification, set thickness greater than 5 cm; each set bounded on bottom by an essentially planar erosional surface (after Allen, 1963, p. 109); *C*, omicron cross-strata in the Sharon Conglomerate in Gorge Metropolitan Park; *D*, overturned tops on omicron cross-strata in Gorge Metropolitan Park; *E*, pi cross-stratification, set thickness greater than 5 cm; each set bounded on bottom by an erosional scoop-shaped surface (after Allen, 1963, p. 109); *F*, pi cross-strata in Gorge Metropolitan Park.



on bar tops, but this type is quantitatively insignificant.

A cross-stratified body is defined as one consisting of layers deposited at an angle to the original dip of the formation and separated from adjacent layers by surfaces of erosion, nondeposition, or abrupt change in character (fig. 10A). A set is one unit of conformable cross-strata which is separated from other sedimentation units by surfaces of erosion, etc., and a coset is two or more sets of cross-strata of the same character (fig. 10A). The terminology for crossbedded bodies changes with variations in coset thickness. Allen (1963) recognized small-scale and large-scale cosets; where the thickness of a set is less than 5 cm, it is classified as small scale, where more than 5 cm, large scale.

Omicron cross-stratification comprises an entire Sharon outcrop in some places (fig. 10B, C). The thickness of individual sets ranges from a minimum of about 6 inches to a maximum of about 6 feet; the average thickness is about 1.5 feet (Fuller, 1955). Some isolated small-scale sets occur within cosets, pinching out laterally in a few feet and probably representing remnants of large-scale sets which have been partially eroded. Each set is underlain by an essentially planar erosional surface which is not necessarily horizontal; this surface is commonly covered by a lag concentrate one pebble thick. Small sets, 10 to 15 feet long, are commonly lenticular to wedge shaped; larger sets are tabular in nearly every case and may be tens of feet long with little change in thickness.

Individual crossbeds of each set commonly range from 1.5 to 2 inches in thickness (Fuller, 1955), range in dip from 11 to 32 degrees, and are discordant with both lower and upper contacts. In a section parallel to the direction of current flow, the cross-strata are mostly steeply dipping. In a section at right angles to current flow, the strata are observed as essentially even horizontal layers. Unlike the sets described by Allen (1963) the sets comprising a coset in the Sharon Conglomerate are not all oriented in the same direction, but have enough variance that no exposure will give the appearance of only horizontal stratification within the coset. Where the traces of the crossbed can be seen in plan view they are straight and essentially parallel, with only minor deviations. Grading of the individual cross-strata updip and at right angles to dip is common. In a few places sets of omicron cross-strata can be observed to have overturned tops (fig. 10D). Overturning in every case appears to be in a downstream direction.

Pi cross-stratification (fig. 10E, F) consists of interfering large-scale sets ranging from about 2 inches to 2 feet in thickness. The bottom contact of each set is an erosional scoop-shaped surface plunging at one end only. The sets are formed of curved crossbeds discordant with the surface of the underlying set; discordance is seen clearly in the vertical section that follows the trough axis. In plan view the traces of the crossbed are curved and interfering. Individual crossbeds may show graded bedding.

Pi cross-stratification occurs in two different situations in the Sharon Conglomerate. In one case it occurs in small channels that cut the Sharon sandstones and in which coarser grained material was deposited parallel to the contour of the channel in the form of trough crossbedding. In the second case the pi cross-stratification forms sets which occur in tabular or wedge-shaped cosets similar to those described for omicron crossbedding; the cosets are bounded by planar erosional surfaces which almost always separate pi crossbedding from overlying and underlying omicron crossbedding. Pi crossbedding is common but not abundant. It occurs both in the sandstones and in the conglomerates.

Mrakovich (1969b) measured dip azimuths on 113 sets of cross-strata at 15 Sharon localities in northeast

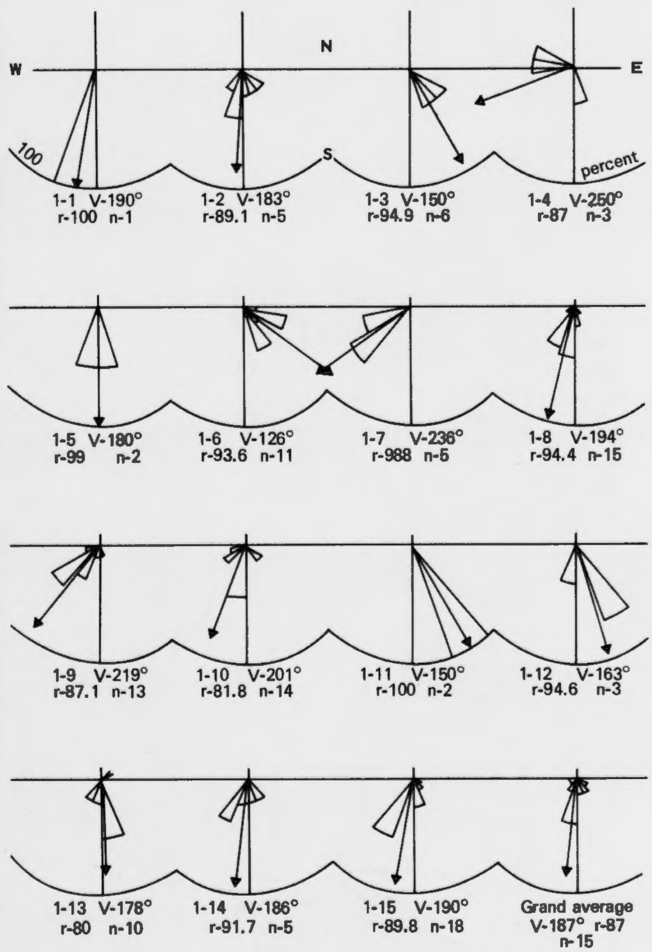


FIGURE 11.—Rose diagrams summarizing cross-bedding dip azimuths in 20° class intervals; arcs equal 100°; 1 is outcrop number shown in figure 3, V is vector mean represented by direction of arrow, r is vector magnitude in percent represented by length of arrow, and n is number of measurements (from Mrakovich, 1969b).

Ohio. These data are summarized in figure 11. In general, dip directions were in a southerly direction, indicating a general direction of flow from north to south, consistent with the regional interpretation (fig. 12) of a generally northern source land during early Pottsville time. It is noteworthy that there is little variance between azimuths measured on several sets at a single locality. The majority of measurements were taken on omicron sets deposited when the entire channel was in flood; relatively unidirectional cross-stratification would tend to be produced under such circumstances.

Horizontal stratification is volumetrically minor and in places lacking entirely in outcrops of the Sharon Conglomerate. Where best developed it occurs in the conglomerates and may reach a maximum thickness of about 6 feet; the bedding occurs as a tabular set of laminae which are nearly horizontal. The lower boundary of each set is a horizontal planar erosional surface. In the sandstones horizontal strata commonly occur as thin discontinuous beds.

Distribution of lithologies and bedding types

Although called the Sharon Conglomerate, in northeastern Ohio sandstone is quantitatively the most abundant rock type in the formation; some conglomerate occurs as tabular bodies in the sandstones, but the major conglomerates are confined to what appears to be two or three narrow north-south-trending belts (Bowen, 1953; Fuller, 1955). The most distinct belt (fig. 13) extends south of Thompson, Geauga County, for 7 miles and is probably the same one that reappears 17.5 miles south at Nelson Ledge State Park in Portage County, where its outcrop extends for 4 miles. A second belt trends northeast-southwest near Hambden, Geauga County, and is aligned with a 4-mile-long linear belt just south of Chardon, also in Geauga County. Other outcrops of conglomerates which may be part of the second belt mentioned are located 1 mile west of Bainbridge, at Copley, and along Interstate 76 in west Akron.

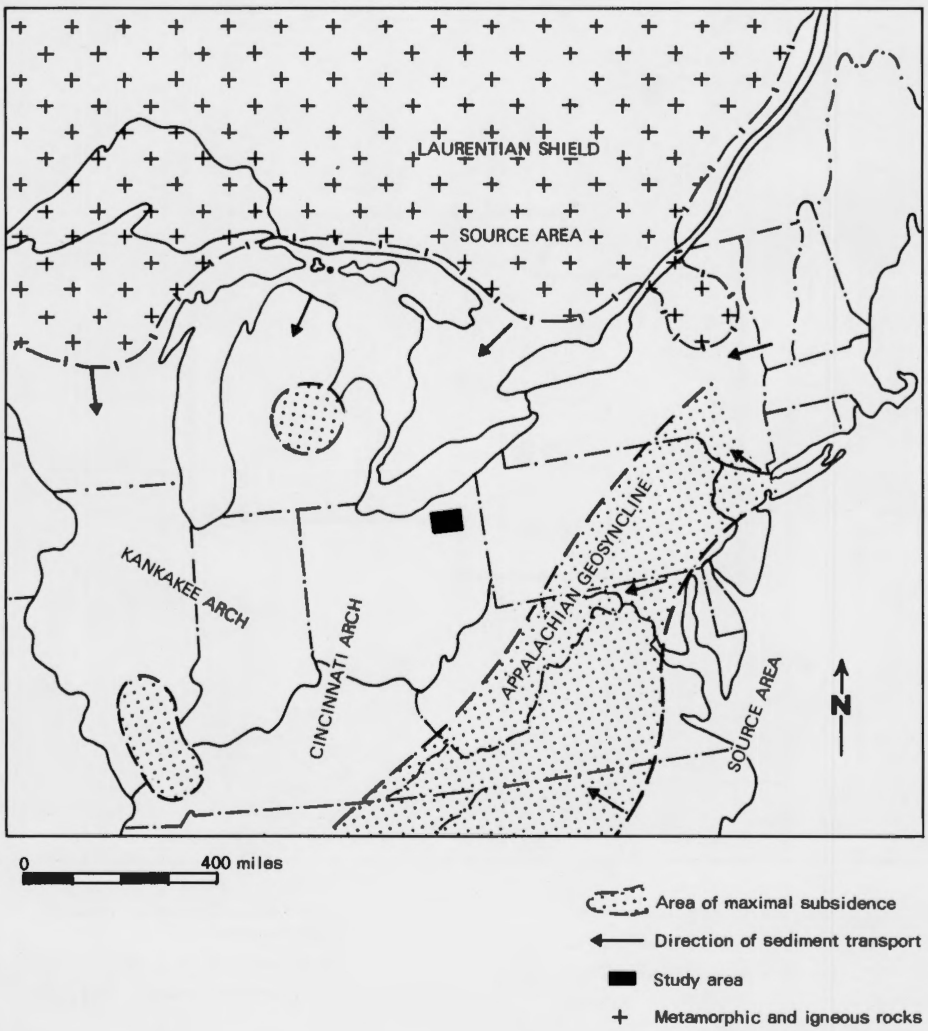


FIGURE 12.—Regional setting during the Early Pennsylvanian (modified from Siever and Potter, 1956, p. 332).

In contrast to the conglomerates the beds immediately above the Mississippian disconformity may consist of medium-grained quartzarenite. In this case crossbedding is nearly all the planar (omicron) type, with minor amounts of small-scale (nu) trough crossbedding and either little or no horizontal stratification. Uniform tabular conglomerate beds 3 to 6 inches thick commonly are scattered through the sandstone.

Significance of variation in texture and structures

The upward decrease in grain size seen in the conglomerates and conglomeratic sandstones of the Sharon and the associated upward distribution of pri-

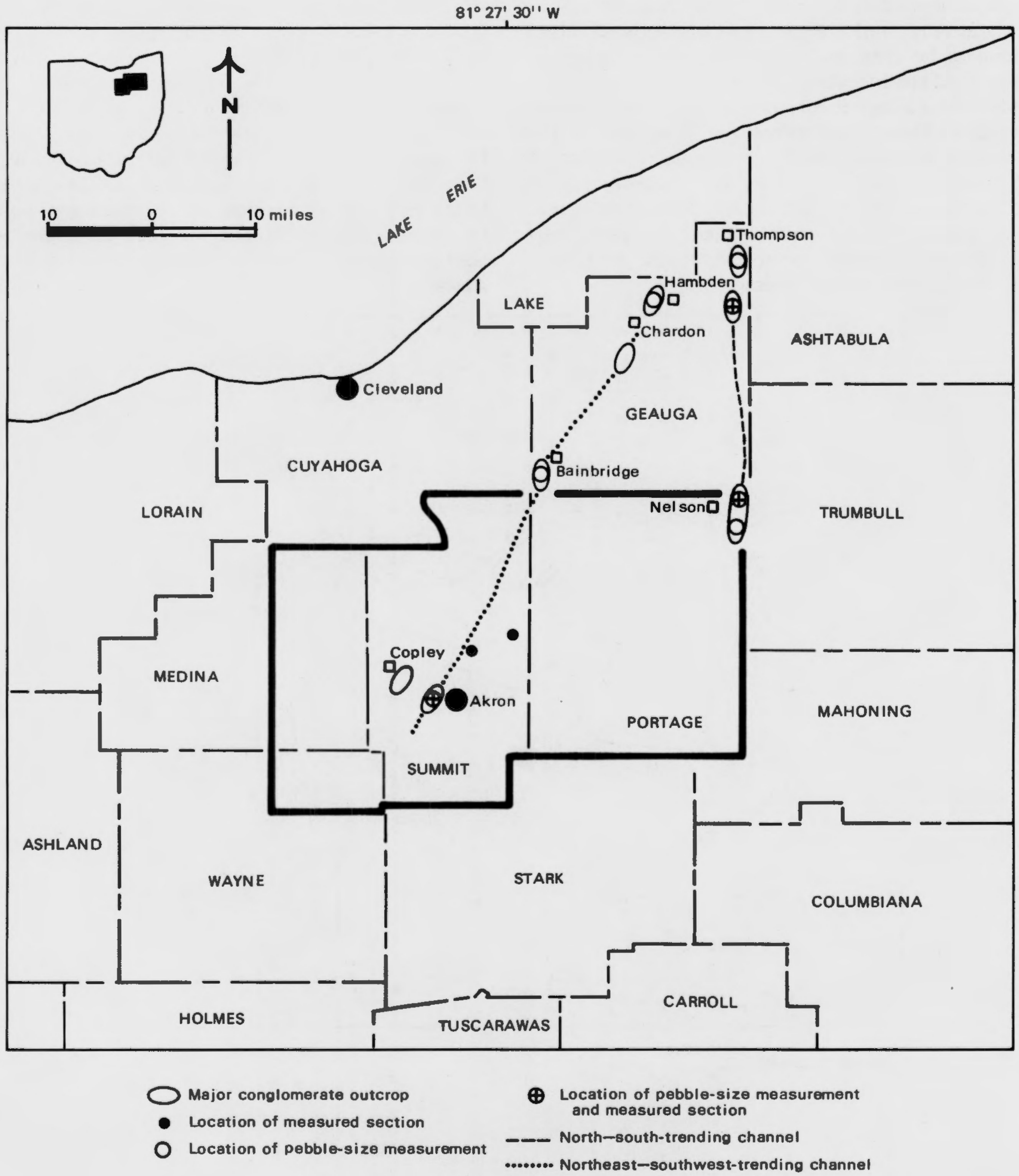


FIGURE 13.—Locations of conglomerate belts, measured sections, and pebble-size measurements of the Sharon Conglomerate in northeastern Ohio; Portage and Summit Counties and portions of Medina and Wayne Counties (shaded) are the main area of interest (from Mrakovich, 1969b).

mary structures from basal horizontally stratified conglomerates to trough- and planar-crossbedded sets of conglomeratic sandstones indicate a vertical decrease in flow energy and competency. Similar vertical sequences of textures and primary structures from ancient and recent sediments were cited by Harms and Fahnestock (1965), Visher (1963), Allen (1962a, 1962b, 1963), and many other workers, who interpreted them to be formed by laterally migrating rivers.

In careful flume experiments Simons and Richardson (1961) and Simons *et al.* (1965) demonstrated that flow energy and competency can be correlated with bed roughness forms arising by interaction between the bed material and flow. The sequence of these bed forms with increasing intensity of flow was:

1. plane bed with no sediment movement,
2. small-scale ripples,
3. large-scale ripples, sand waves, or dunes,
4. large ripples,
5. plane beds with sediment movement,
6. stationary antidunes, and
7. moving antidunes.

Each of these bed forms produces a different sedimentary structure, and each is commonly developed in both recent and ancient fluvial deposits (Harms *et al.*, 1963; Allen, 1963; Bernard and Major, 1963). Table 1 shows the relationship between bed roughness forms and the characteristic internal structures they imprint on stream deposits.

In laterally migrating channels where stream velocities decrease from deeper parts to shallower parts of the channel an accreting point bar shows a vertical sequence of structures reflecting the change in flow intensity. As explained before, this vertical sequence of structures and textures produced by the point-bar formation is known to be characteristic of this type of river (Visher, 1963) and is similar to the sequence of structures and textures exhibited by many of the coarse-grained rocks of the Sharon Conglomerate, although not the bulk of them. The Sharon sandstones which have predominantly planar-crossbedded sets do not resemble the typical point bar because, quantitatively, trough crossbedding should predominate.

TABLE 1.—*Sedimentary structures in relation to bed form*

Structure	Bed form
Small-scale crossbedding, trough or planar. Sets measured in mm or cm and forming coset	Small-scale ripples, lunate, linguoid, or straight crested
Large-scale crossbedding, trough or planar. Sets measured in dm or m and forming coset	Large-scale ripples, lunate, linguoid, or straight crested
Flat bedding with primary lineation. Sand marked by essentially horizontal, plane, or gently undulating laminae a mm or so thick	Plane bed or stationary low-amplitude antidune

Planar, tabular crossbedding of the type predominating in the Sharon Conglomerate is related to bed forms which are best described as bars (Visher, 1965; Harms and Fahnestock, 1965; Ore, 1964). Harms and Fahnestock describe planar crossbedding in point-bar deposits in the Rio Grande. There planar crossbedding was never found more than two feet below the surfaces of point bars and was not quantitatively important. This crossbedding was produced by nearly flat, rippled, or plane-bedded bars of varying size and with sinuous relatively long avalanche faces on the down-current margins. The largest of these bars occurred on

TABLE 2.—*Relationship of flow velocity to flow regime, bed forms, bedding types according to Allen's classification (1963), mode of sediment transport, and phase relationship between bed and water surfaces (modified from Simons* et al., *1965, p. 36)*

Increasing flow velocity	Flow regime	Bed form	Most commonly associated bedding types	Mode of sediment transport	Phase relation between bed and water surfaces
	Lower flow regime	Ripples	Nu cross-stratification	Discrete steps	Out of phase
		Ripples on dunes	Nu and pi cross-stratification		
		Dunes			
		Bars?	Omicron cross-stratification		
	Transition	Washed out dunes and bars?	Nu, pi, and omicron cross-stratification		
	Upper flow regime	Plane beds	Horizontal stratification	Continuous	In phase
		Antidunes	——		
		Chutes and pools	——		

FIGURE 14.—Mary Campbell Cave. The Sharon-Meadville disconformity is shown in the lowest third of the photograph.

the downstream ends of the point bars.

The relationship between the bed forms, bedding types as shown in table 1, and the generalized flow regime of a stream in terms of increasing velocity is shown in table 2. The higher velocity bed forms such as antidunes and chutes and pools apparently leave no preservable bed forms. In the lower flow regime the sediment is moved in discrete steps, and the surface of the water in the stream is out of phase with the bed form. At higher velocities, that is, in the upper flow regime, the form of the bed mimics the form of the water surface above. In the range of velocities between the two the dunes and bars are washed out to form the crossbeds, which give way to the plane bed and horizontal stratification at just a little higher velocity.

STOP 1 – GORGE METROPOLITAN PARK

Geomorphic features

Cuyahoga River gorge.—The gorge is about 170 feet deep and 1.5 miles long. It is a fine example of a youthful valley, as is indicated by its V-shaped cross section, by the virtual absence of a floodplain, and by the rapids or falls developed on resistant siltstones of the Sharpsville Member of the Cuyahoga Formation.

Although most of the cutting of the gorge was accomplished during post-Pleistocene time, the excavation of this new segment of the Cuyahoga valley began in the late Pleistocene when the last Wisconsinan glacier retreated to the north of Cuyahoga Falls and ponded the drainage. Spillway waters from the rising glacier-dammed lake were forced over a col in a divide near the present location of the city of Cuyahoga Falls and established the geographic position of the incipient gorge. As the glacier retreated to the north of Ohio the lake was drained, and the stream in the incipient gorge was reversed to its present direction of flow toward Lake Erie.

Mary Campbell Cave.—Most of the springs in northeastern Ohio are located at the contact between the Sharon Conglomerate (the outstanding bedrock aquifer in the region) and the underlying impermeable shales of the Cuyahoga Formation. At the Mary Campbell Cave locality spring sapping at the contact has eroded back the soft shales of the Meadville Member of the Cuyahoga Formation and formed a recessive lower wall beneath a jutting ledge of resistant conglomerate whose lower portion has collapsed (fig. 14).

Honeycomb weathering.—A distinctive type of differential weathering commonly develops on exposed

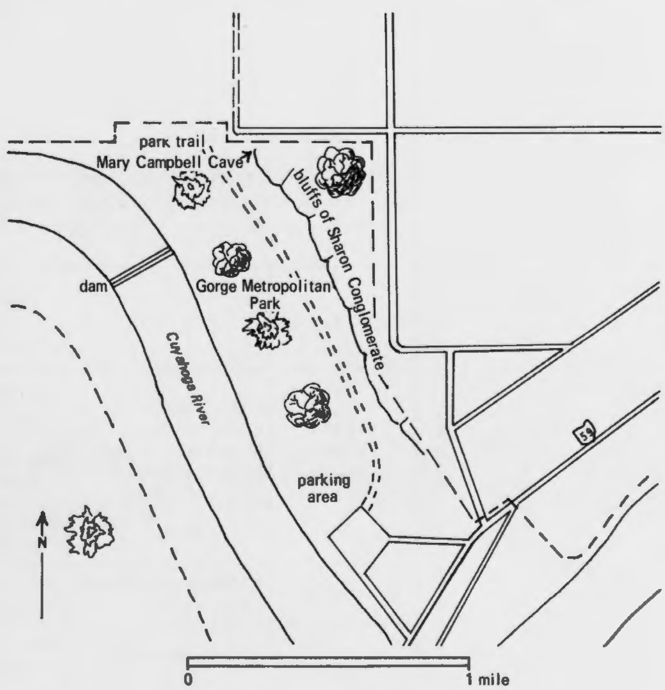


FIGURE 15.—Sketch map of Gorge Metropolitan Park, Cuyahoga Falls, Ohio.

outcrop faces of Sharon Conglomerate. Although the honeycombs in this unit have never been thoroughly studied, it is suggested that differential cementation of the component grains may be a contributive factor in formation of the honeycombs.

Mass wasting.—In addition to the usual agents or processes of mass wasting (gravity, water, ice, root wedging, spring sapping), bedding planes and joints in the Sharon Conglomerate facilitate the downslope movement of material by separating this unit into discrete blocks, many of which are strewn about the valley walls. The two dominant joint sets in the Sharon at this locality trend N. 80°W. and N. 20°E.

Stratigraphic units

Cuyahoga Formation.—The lowest three-quarters of the gorge walls is composed of fossiliferous shallow-water marine shales and siltstones of the Lower Mississippian (Kinderhook) Cuyahoga Formation. Sole markings and other sedimentary structures in these strata indicate that they were derived from the main Appalachian belt of orogenic uplift located to the east. Both the Cuyahoga and the overlying Sharon sediments were deposited near the western margin of the Appalachian exogeosyncline.

The following stratigraphic section was measured on the north wall of the Cuyahoga River gorge, about one-quarter mile west of Mary Campbell Cave. The base of the section is at the water level of the Cuyahoga River.

	Thickness (ft)
PENNSYLVANIAN SYSTEM	
Sharon Conglomerate	40
regional unconformity	
MISSISSIPPIAN SYSTEM	
Cuyahoga Formation	
Meadville Member (mostly gray shale)	105
Sharpsville Member (mostly siltstone)	36
Orangeville Member (mostly gray shale)	12

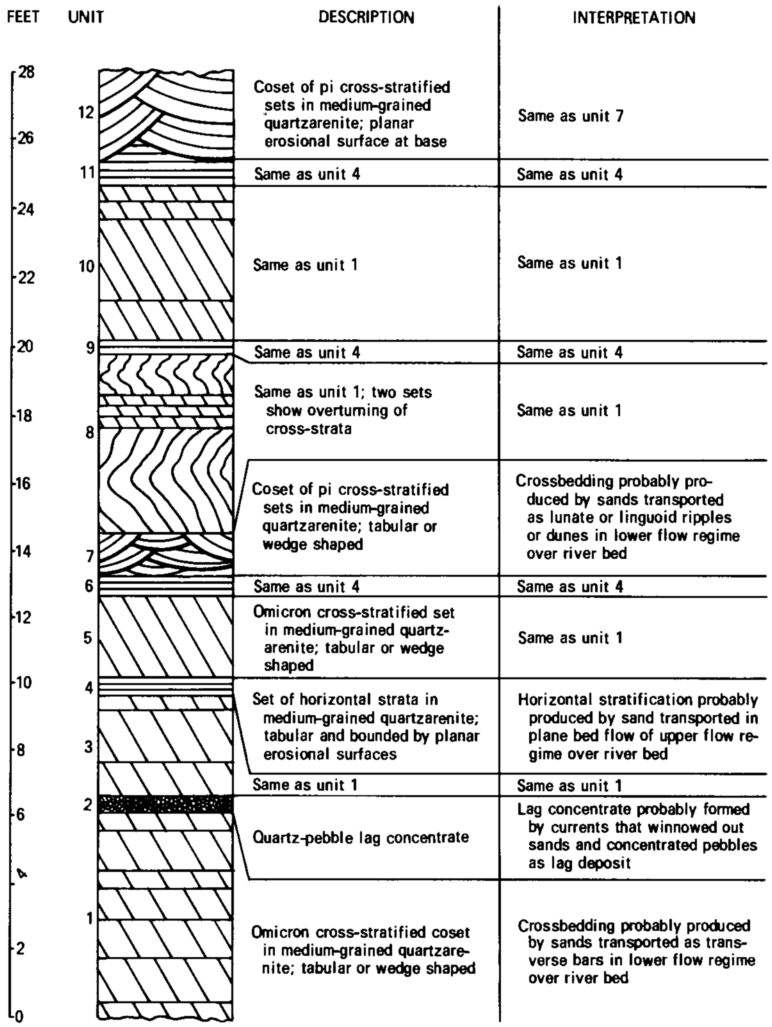


FIGURE 16.—Measured section of the Sharon Conglomerate at Gorge Metropolitan Park (see fig. 3) on north side of Akron, in Cuyahoga Falls, Ohio (Mrakovich, 1969b).

Sharon Conglomerate.—Outcrops of the sandy facies of the Sharon Conglomerate extend along the high banks of the Cuyahoga River in Gorge Metropolitan Park (fig. 15) and may be studied conveniently by taking a short walk along the main park trail from the parking lot to Mary Campbell Cave. A well-exposed outcrop (fig. 10C) uphill from the trail shows a sequence of predominantly high-angle omicron crossbeds interspersed with thin units of gravel, horizontally bedded units, and pi-crossbedded sets. The overturned crossbeds are interesting to note. The top of the outcrop exposes large cosets of pi crossbeds.

No hammers please — park rule

A. Walk from parking lot along trail and assemble at Mary Campbell Cave.
   1. Note the contact of the Sharon Conglomerate with the underlying Meadville Member of the Lower Mississippian Cuyahoga Formation. As can be seen from figure 14 there is considerable relief on the Mississippian surface. It is reasonable

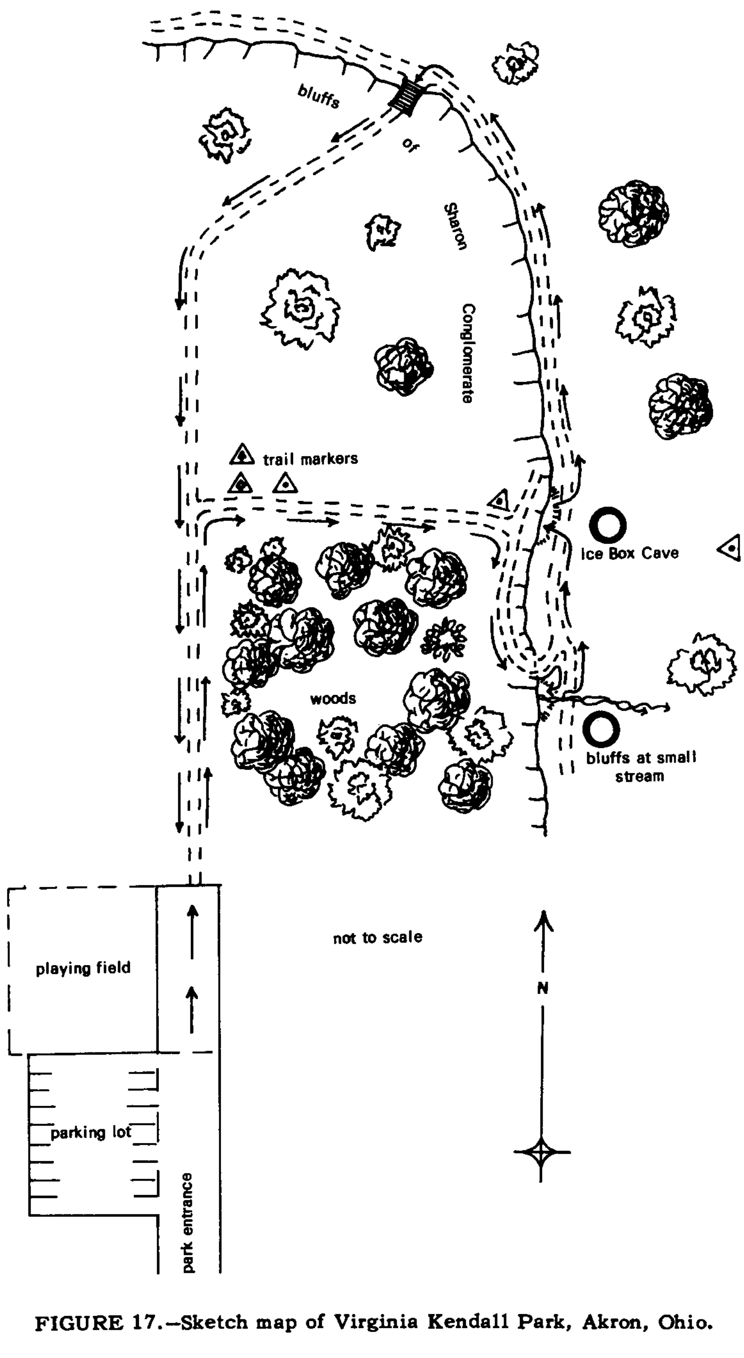


FIGURE 17.—Sketch map of Virginia Kendall Park, Akron, Ohio.

to assume that the contact exposed here is a rather high-elevation burial of the Mississippian strata by the Sharon River (note that this is locality 10 on fig. 3).

2. Note the worm's eye view of the gravelly stream bed on the roof of the cave.
3. Note the lithology at the base of the Sharon. Zones of the "Harrison Ore" and iron-stained Sharon Conglomerate can be found at many exposures of the basal portions of the formation. For example, at the Phalanx Quarry of the Industrial Silica Corporation, 3 miles east of Garrettsville, Portage County, marcasite cements the basal few inches of the conglomerate.
4. Note the large fractures in the Sharon at the side of the cave. These provide considerable groundwater locally in northeastern Ohio.

B. Walk back along the trail 50 feet and follow the outcrop up the slope. Follow the trail along the base of the Sharon (as exposed) in the cliff until you come to the cutaway part of the cliff (just up from the small house on the trail) about 100 yards from Mary Campbell Cave. This site is an excellent spot at which to observe the bedding features of the Sharon Conglomerate.

1. Compare the bedding types (fig. 10) with the bedding seen in the outcrop (fig. 16).
2. Compare the vertical sequence of bedding types with the hypothetical sequence (fig. 16 and fig. 8).
3. Note the direction of bedding dip is mainly to the south (fig. 11).
4. Note the overturned bedding (fig. 16, unit 8).
5. Note the pi crossbeds at the top of the cliff (fig. 16, unit 12).
6. Walk along the outcrop and determine the degree of lateral continuity (single stream bar) in this exposure.
7. Look for consistent patterns of grain-size variation in the bedding sets.
8. Note the small cut-and-fill structures.
9. At about eye level on the lower part of the west-

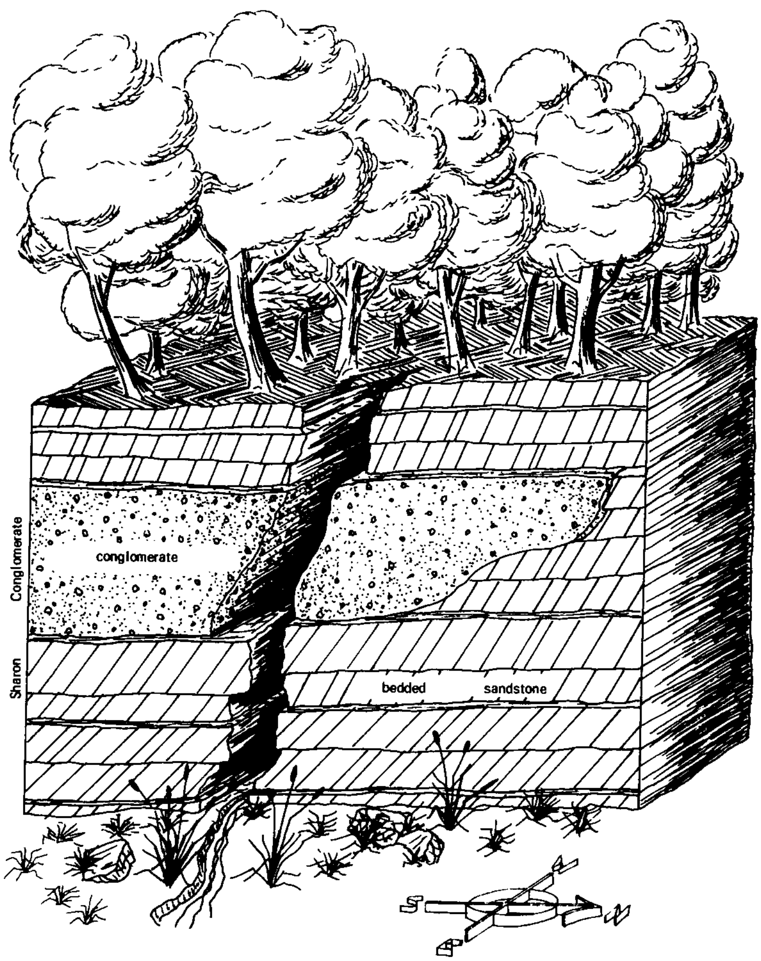


FIGURE 18.—Sketch of exposure at locality 1 near Ice Box Cave in Virginia Kendall Park.

facing cliff note a log of a Pennsylvanian tree.
10. Determine the predominant flow regime of the Sharon River at this point.

Questions:
1. What is the predominant bedding type?
2. What was the predominant flow regime?
3. Is there any reasonable match between depositional models and the outcrop sequence?
4. What can one say about the general setting of the Sharon River from this outcrop? What might be expected upstream (north) or downstream (south)? What variations might be expected laterally?

STOP 2 – VIRGINIA KENDALL PARK

Outcrops of sandy and conglomeratic facies of the Sharon Conglomerate extend around the accessible part of the park. Two sites are easily reached from the parking lot by walking north (fig. 17) along the trail to the trail markers and then turning right and following the trail to the edge of the bluff. Turn right again, walking south about 100 feet and down the trail across the bluffs. At the fork turn right along the base of the cliff about 100 feet to the first location. The second location is at Ice Box Cave, north (back) along the trail about 100 yards.

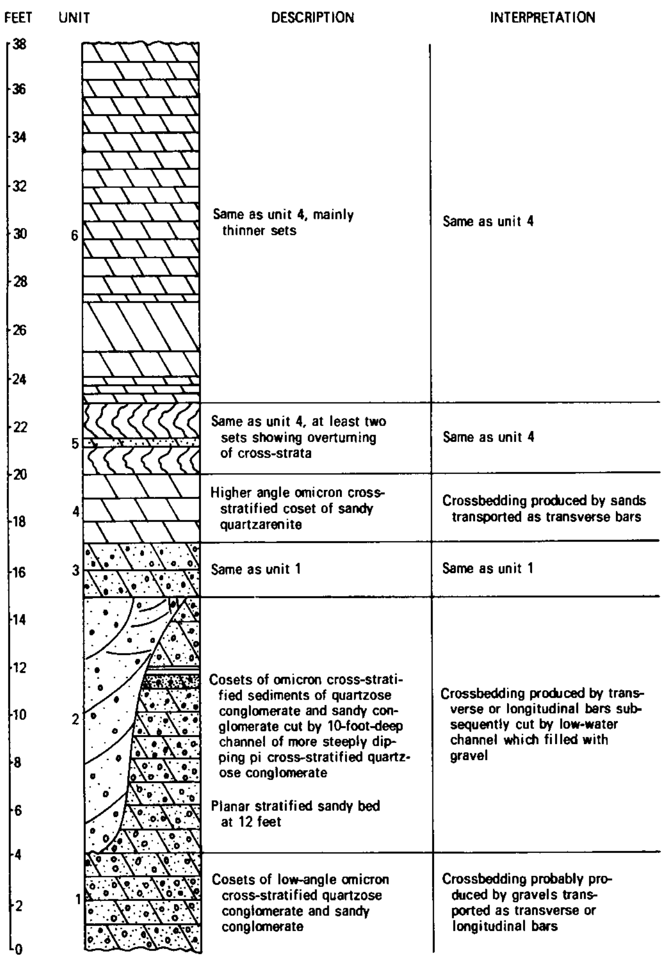


FIGURE 19.—Measured section of Sharon Conglomerate at Ice Box Cave in Virginia Kendall Park.

No hammers please – park rule

A. First location.
   1. Note the gravelly channel (fig. 18) cut in the sandy crossbedded strata.
   2. Note the grain-size variations within beds.
   3. Compare the predominant bedding here with bedding observed at Gorge Metropolitan Park (Stop 1).

B. Walk north on trail to Ice Box Cave (fig. 19).
   1. Note the channel in the lower part of bluff. Other channels can be noted at about the same level by walking along the bluff in either direction.
   2. Note the type of bedding in the channel, in the beds cut by the channel, and in the overlying beds.
   3. Note the generally better sorting and reduction in grain size upward in the section (fig. 19).
   4. Note the lower dip in the gravels and sands of the lower part of the section (units 1, 2, 3) compared with the upper units.
   5. Note the thinner bedded cross-stratified upper units, some with overturned bedding. (Upper part of section is at eye level if one climbs up the joint or walks north on the trail.)
   6. Note the north-south and east-west trend of joint sets.

Questions:
1. What are the predominant bedding types at Stop 2?
2. What are the predominant flow regimes represented at Stop 2?
3. How does the section at Virginia Kendall compare with that at Gorge Metropolitan Park in terms of bedding and flow regime?
4. Is there a reasonable match between outcrop and the hypothetical models?
5. What can you say about the general setting of the Sharon River from observations at this outcrop and at Stop 1?
6. What still unobserved lateral variations might be expected?

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FIELD TRIP NO. 3

ENGINEERING AND PLEISTOCENE GEOLOGY

OF THE

LOWER CUYAHOGA RIVER VALLEY

by

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INTRODUCTION

The Cuyahoga River valley between Akron and Cleveland played a large part in the early economic development of the area. The valley was once the route of the Ohio Canal, opened in 1827, from Akron to Lake Erie. The canal was the means of opening up and developing inland Ohio and of transforming the area from an agricultural to an industrial economy. The Deep Lock Quarry near Peninsula provided most of the dimension stone for the canal locks. In addition, millstones were made from Berea Sandstone quarried at this site.

Industrialization and residential development in the Cuyahoga River valley has had drawbacks. Recently, for example, the Cuyahoga River became internationally infamous as the burning river. In the last five years public pressure to clean up the river has had an impact on future plans for the valley. This strip of undeveloped land between Akron and Cleveland is perhaps best suited for some type of open-space land use. Along these lines a national park has been proposed to preserve the area in the vicinity of this field trip. At present, Cleveland and Akron Park Districts have large holdings in the valley.

The geologic environment is perhaps one of the biggest factors in favor of open-space land use in the Cuyahoga River valley. Large-scale residential developments and industrial complexes might encounter serious geologic and engineering problems: development on the slope would encounter stability problems and development on the lowland would be on the floodplain. This field trip will illustrate some of the many slope-stability problems in the undeveloped area.

Engineering and slope-stability problems that now exist in the valley are the indirect result of the Pleistocene history of the area. Repetitive ice advances into the valley probably resulted in many episodes of drainage ponding between the ice margin and moraines or of stagnant ice left behind in the valley during retreatal stages (Leverett, 1931; White, 1953; Rau, 1969; Wittine, 1970). Some of these events are recorded in over 100 feet of glaciolacustrine silt (the silt has been observed at elevations up to 984 feet above sea level) interbedded with outwash and till; portions of this section are now exposed at various localities in the valley.

The field trip includes seven stops along the lower Cuyahoga River basin in northern Summit County (fig. 1). The purpose of the trip is to show some of the different till-lacustrine silt relationships which document multiple ponding of drainage in the Cuyahoga valley during the Wisconsinan Stage. Lacustrine silt and clay and outwash sand and gravel accumulated during these events and set the stage for many of the slope-failure problems at the stops.

TOPOGRAPHIC MAPS

The route of this field trip may be followed on six U.S. Geological Survey 7½-minute topographic quadrangle maps:

Kent
Hudson
Peninsula (STOPS 1, 2)
West Richfield (short stretch)
Northfield (STOPS 3, 4, 5, 6, 7)
Twinsburg (southwest corner only)

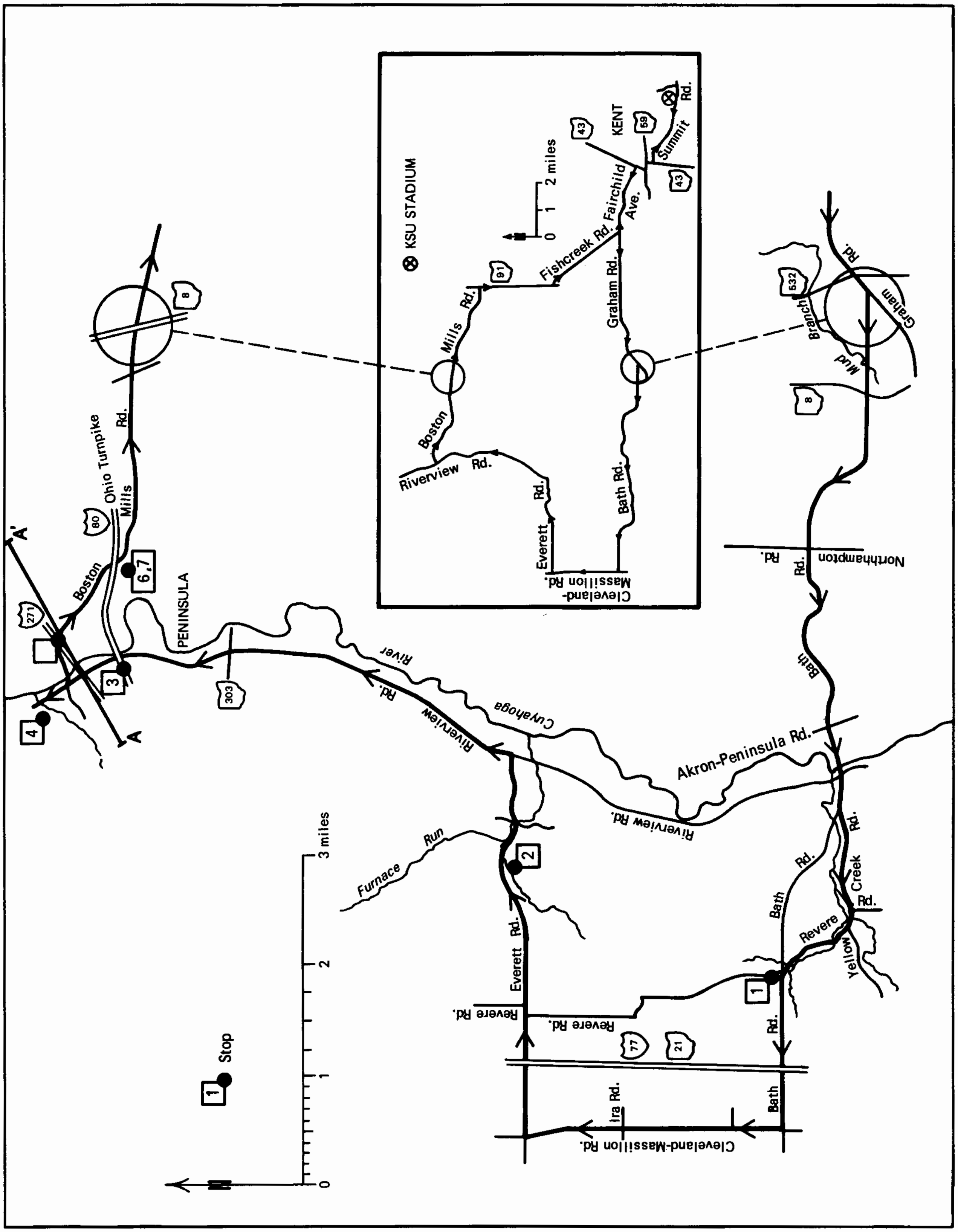

FIGURE 1.—Route of field trip. Line A-A' locates the position of the cross section illustrated in figure 7. Inset map shows the route of the trip, starting at Dix Stadium.

ROAD LOG

Trip will start in parking lot in front of Dix Stadium near intersection of Summit Rd. and Powder Mill Rd.

Mileage		
0		Dix Stadium - proceed west on Summit Rd. The terrane traversed up to the Fish Creek basin is Kent Moraine.
2.1	2.1	Intersection of Summit Rd. and Lincoln St. *Turn right* (north) onto Lincoln St.
2.3	0.2	*Turn left* onto Main St. (Ohio Rte. 59) at traffic light. Cross Cuyahoga River.
3.0	0.7	*Turn right* (north) onto Gougler Ave. at first stoplight after crossing Cuyahoga River.
3.4	0.4	*Turn left* (northwest) onto Fairchild Ave. at Sohio station. Continue northwest on Fairchild.
3.8	0.4	Stop light at intersection of Majors Lane and Fairchild Ave. Entering Fish Creek basin. Fairchild Ave. becomes Fairchild Rd.
Kent quadrangle / *Hudson quadrangle*		
5.1	1.3	Stow city limits. Fairchild Rd. becomes Graham Rd.
6.0	0.9	Intersection of Graham Rd. and Fishcreek Rd. Continue on Graham Rd.
7.9	1.9	Intersection of Graham Rd. and Ohio Rte. 91. Continue west on Graham Rd.
9.4	1.5	Overpass over Ohio Rte. 8. Sediments exposed along Rte. 8 are lacustrine silt interbedded with outwash. Highway exploration cores from ¾ mile southwest of this intersection show lacustrine silt on top of Kent(?) Till at a depth of 12 feet.
10.8	1.4	Intersection of Graham Rd. and Bath Rd. Sohio station at corner. *Turn right* (west) onto Bath Rd.
Hudson quadrangle / *Peninsula quadrangle*		
11.5	0.7	Cross Mud Brook.
11.6	0.1	Fisher-Fazio store on left; building built on fill was damaged owing to improper compaction of fill.
11.7	0.1	Intersection of Bath Rd. and Ohio Rte. 8. Continue west on Bath Rd.
13.4	1.7	Intersection of Bath Rd. and Northampton Rd. Continue west on Bath Rd.
13.9	0.5	Hiram Till exposed in bank on right.
14.7	0.8	Start descent into Cuyahoga River valley.

15.1	0.4	Intersection of Bath Rd. and Akron Peninsula Rd. Continue west on Bath Rd.
15.5	0.4	Cuyahoga River.
15.6	0.1	Intersection of Bath Rd. and Riverview Rd. Continue west on Bath Rd. Bluff off to the right (north) is composed of lacustrine silts capped with Hiram Till.
15.9	0.3	Intersection of Bath Rd. and Yellow Creek Rd. *Keep left*, follow Yellow Creek Rd. Note several terrace levels along Yellow Creek; Yellow Creek in this area follows the Wabash Moraine.
16.9	1.0	Intersection of Yellow Creek Rd. and Revere Rd. These continue together as the same road for 0.2 mile.
17.1	0.2	Yellow Creek Rd. and Revere Rd. divide. *Turn right* (north) onto Revere Rd.
17.9	0.8	STOP 1. Intersection of Revere Rd. and Bath Rd.
18.7	0.8	Proceed west on Bath Rd., which goes under Ohio Rte. 21. Highway exploration core for Rte. 21 overpass shows 62 feet of lacustrine silt and outwash, capped by till (Hiram?).
Peninsula quadrangle / West Richfield quadrangle		
19.3	0.6	Intersection of Bath Rd. and Cleveland-Massillon Rd. *Turn right* (north) onto Cleveland-Massillon Rd.
20.7	1.4	Intersection of Cleveland-Massillon Rd. and Ira Rd. Continue north on Cleveland-Massillon Rd.
21.6	0.9	Intersection of Cleveland-Massillon Rd. and Everett Rd. *Turn right* (east) onto Everett Rd.
22.2	0.6	Overpass across Ohio Rte. 21.
West Richfield quadrangle / Peninsula quadrangle		
22.7	0.5	Intersection of Everett Rd. and Revere Rd. Continue east on Everett Rd.
24.0	1.3	STOP 2. Everett Rd. slide.
24.4	0.4	Continue east on Everett Rd. Covered bridge over Furnace Run.
25.0	0.6	Intersection of Everett Rd. and Riverview Rd. *Turn left* (north) onto Riverview Rd.
25.8	0.8	Bedford Shale outcrop along left (west) side of road.
26.3	0.5	Peninsula village limits.
26.9	0.6	Deep Lock Quarry Metropolitan Park.

27.3	0.4	Quarry in Berea Sandstone visible on right (east) side of road.
27.8	0.5	Village of Peninsula. Intersection of Riverview Rd. and Ohio Rte. 303. Continue north on Riverview Rd.
Peninsula quadrangle / *Northfield quadrangle*		
28.8	1.0	STOP 3. Riverview Rd. landslide at Ohio Turnpike bridge.
29.3	0.5	Continue north on Riverview Rd. Intersection of Riverview Rd. and Boston Mills Rd.
29.5	0.2	Continue north on Riverview Rd. STOP 4. Boston Mills Rd. slide.
29.7	0.2	Proceed south on Riverview Rd.
29.8	0.1	Intersection of Riverview Rd. and Boston Mills Rd. *Turn left* (east) onto Boston Mills Rd.
30.0	0.2	Cross Cuyahoga River. The river flows over the Chagrin Shale in this stretch.
30.3	0.3	Road forks at church. Keep right, following Boston Mills Rd.
31.1	0.8	STOP 5. Beneath I-271 overpass.
31.2	0.1	Continue southeast on Boston Mills Rd. Note slides and erosion of slide scars. STOPS 6 and 7. Boston Mills Rd. on southwest side of Ohio Turnpike overpass.
32.9	1.7	Continue southeast on Boston Mills Rd. Intersection of Boston Mills Rd. with Olde Eight Rd. Continue east on Boston Mills Rd.
33.3	0.4	Intersection of Boston Mills Rd. with Ohio Rte. 8. Continue southeast on Boston Mills Rd.
Northfield quadrangle / *Twinsburg/Hudson quadrangles*		
36.1	2.8	Intersection of Boston Mills Rd. and Streetsboro Rd. (Ohio Rte. 303). *Turn left* (east) onto Streetsboro Rd. Proceed east into village of Hudson.
36.7	0.6	Intersection of Streetsboro Rd. (Ohio Rte. 303) and Ohio Rte. 91. *Turn right* (south) onto Rte. 91.
38.2	1.5	Intersection of Ohio Rt. 91 and Fishcreek Rd. *Turn left* (southeast) onto Fishcreek Rd.
41.4	3.2	Intersection of Fishcreek Rd. and Graham Rd. *Turn left* (east) onto Graham Rd.
Hudson quadrangle / *Kent quadrangle*		
42.0	0.6	Kent city limits. Graham Rd. becomes Fairchild Rd.

43.4	1.4	Intersection of Fairchild Ave. and Majors Lane.
43.8	0.4	Intersection of Fairchild Ave. and N. Mantua St. (Ohio Rte. 43). *Turn right* (south) onto N. Mantua St.
44.3	0.5	Continue south on N. Mantua St. across Main St. to Stow St. *Turn left* (east) on Stow St.
44.4	0.1	Cross Cuyahoga River.
45.0	0.6	Stow St. becomes Summit St. on east side of Cuyahoga River. Continue east on W. Summit St. Intersection of E. Summit St. and Lincoln St. McGilvrey Hall on corner. KSU campus.

BEDROCK TOPOGRAPHY AND DRAINAGE

The bedrock underlying the Quaternary deposits in northern Summit County consists of Upper Devonian, Mississippian, and Pennsylvanian sandstones, siltstones, and shales that dip gently toward the southeast. Subsurface data indicate that the bedrock topography in this area consists of rather elongate hills separated by several northwest-southeast parallel-trending valleys (fig. 2) that were probably part of the Dover River (Stout, Ver Steeg, and Lamb, 1943; Rau, 1969), a Teays-stage stream that flowed northward.

The preglacial drainage has probably exercised considerable control on all subsequent drainage in the lower Cuyahoga valley. The drainage following each ice advance would tend to follow the debris-filled older valleys because these valleys were probably topographically lower than the surrounding drift-veneered bedrock uplands and because the unconsolidated material in the valley would be more easily eroded. The Cuyahoga River north of Cuyahoga Falls flows over several hundred feet of valley fill, but still essentially follows the Teays-stage drainage. Depths to bedrock in the deeper parts of the valley are unknown; a water-well log from near the intersection of Bath and Riverview Roads at an elevation of 750 feet had not reached bedrock at a depth of 305 feet (White, 1953).

STRATIGRAPHY

General considerations

The primary stratigraphic problems in this area relate to correlation of till units. At the present time we are not able to confidently correlate these units with those recognized in the adjacent Killbuck and Grand River lobes (fig. 3; table 1). Distinctive till sheets in these two lobes are recognized by color of oxidized till, texture, mineralogy, and depth of weathering (White, 1969); all these criteria are difficult to apply within this interlobate area. For example, the uppermost till in the field trip area should be Hiram Till. In its "typical" occurrences in the adjacent Killbuck and Grand River lobes the Hiram Till contains no kaolinite (Winslow and White, 1966). At Stop 4 the uppermost till, stratigraphically and topographically, should be the Hiram Till, but X-ray diffraction analysis of this material indicates the presence of kaolinite; chlorite and illite are also present, with illite being the dominant clay mineral. One sample of each till viewed on the field trip was analyzed; this is a limited sampling, but all the tills show remarkably similar clay mineral X-ray diffraction patterns. Furthermore, the clay mineral suites in the lacustrine clayey silt and in the bedrock (Chagrin Shale exposed beneath till at Stops 3 and 4) are almost identical to those in the tills. These data suggest that perhaps some of the difficulties encountered in trying to identify and correlate the till units in the valley with those in the adjacent lobes are caused by enrichment of the valley tills with silt and clay derived from the local bedrock and with materials reworked from sediments deposited during earlier lacustrine events in the valley.

Pre-Wisconsinan deposits

No pre-Illinoian drift has been positively identified in the lower Cuyahoga River valley. However, on the basis of reports in the literature (Lessig and Rice, 1962; Lessig, 1964; Totten, Moran, and Gross, 1969; White, 1969) of pre-Illinoian deposits in northeast Ohio it seems reasonable to speculate that materials of this age might occur in the buried valley fill.

Illinoian drift has not been recognized in the field trip area; however, several miles downstream, drift of this age occurs in Cuyahoga County in exposures along Chippewa Creek and Mill Creek, two tributaries of the Cuyahoga River (Winslow, White, and Webber, 1953; White, 1965, 1968).

Wisconsinan deposits

Wisconsinan ice advancing into northeast Ohio was split into two lobes as the result of topography. The western segment, the Killbuck lobe, moved southeast down the low area between the highlands in Richland County on the west and those in Summit and Geauga Counties on the east. Ice of the Grand River lobe flowed southward through the Grand River lowland (White, 1967). The area to be visited on the field trip was situated between these two lobes during much of Woodfordian time. However, the ice that deposited the

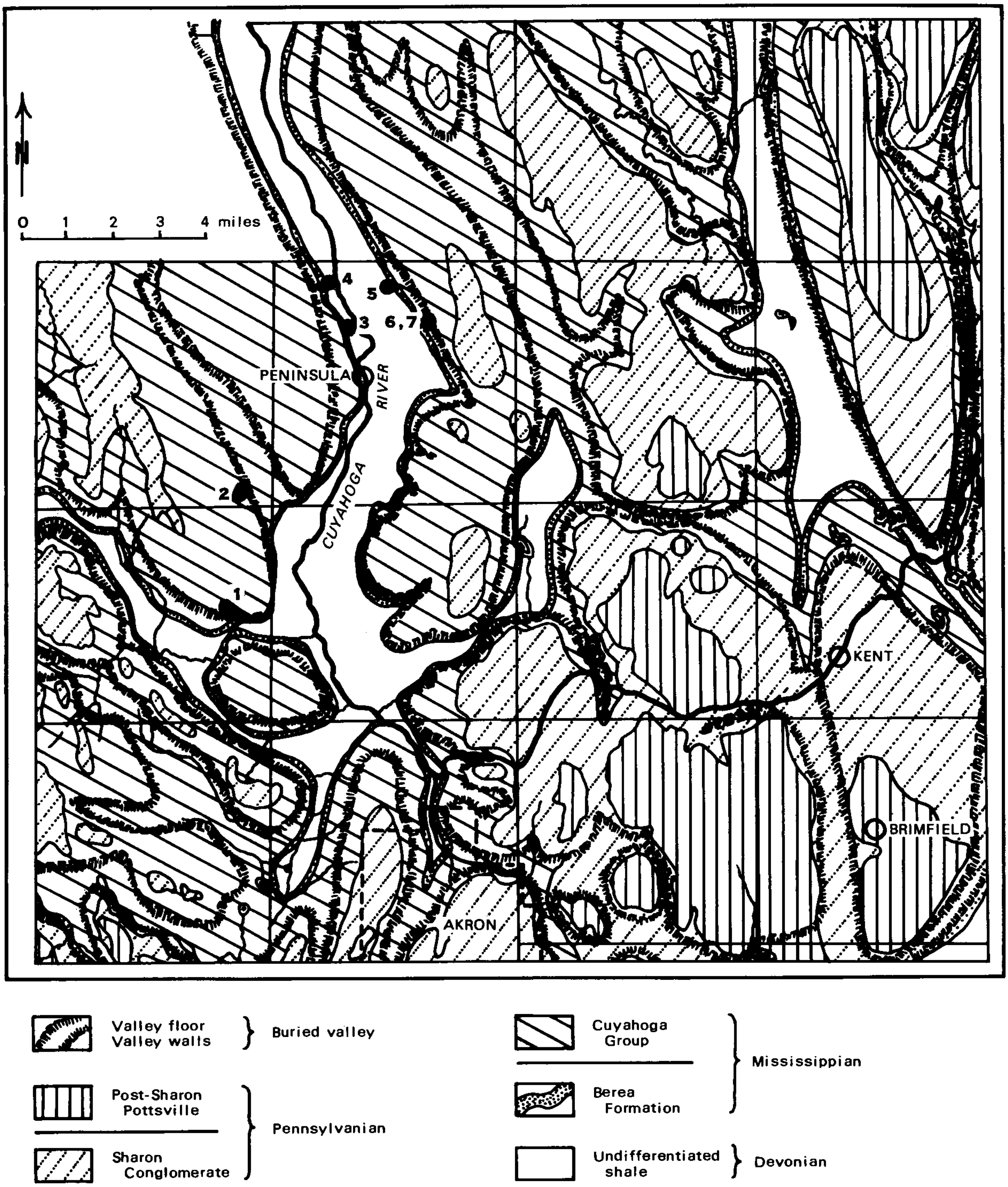

FIGURE 2.—Geology and bedrock topography within the area covered by the road log in figure 1. (Modified from Rau, 1969.)

Hiram Till advanced into the area during late Woodfordian time as part of the Cuyahoga sublobe of the Killbuck lobe (fig. 3).

Wisconsinan ice advanced into northeast Ohio and assumedly into the Cuyahoga River valley in three separate substages (fig. 4). The earliest advance (dated as early Altonian) into this area is represented by a thoroughly weathered greenish-gray till in the valley of Mill Creek at Garfield Heights in Cuyahoga County (Dreimanis, 1969). The till, which occurs below Farmdalian loess and above a Sangamonian soil, is believed to have been deposited by the same ice advance that produced the Canning and Upper Bradtville Tills across Lake Erie in southern Ontario (Dreimanis and Karrow, 1972). A second ice advance into this area (late Altonian) deposited the Mogadore, Millbrook, and Titusville Tills. The last ice advance into northeast Ohio (Woodfordian) consisted of four pulses of decreasing vigor; each readvance did not reach as far south as the previous oscillation. The Kent and Navarre, Lavery and Hayesville, and Hiram and Ashtabula Tills were deposited during this substage. Some of the characteristics of the pre-Ashtabula Wisconsinan tills are summarized in table 1.

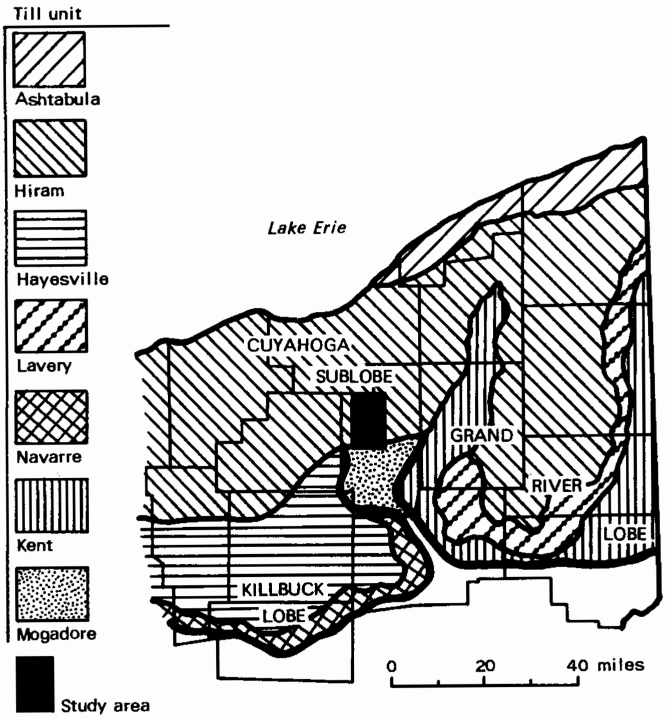

FIGURE 3.—Areal distribution of till sheets exposed at the surface within the Killbuck and Grand River lobes. Note the essentially interlobate position of the area to be visited. (Modified from White, 1969.)

STOP 1 – BATH ROAD

This roadcut on Bath Road shows the relationship between a till (Lavery?) and lacustrine silts. At this site the oxidized calcareous yellow-brown (10*YR* 6/6) till (unit 5, table 2) contains 41 percent sand, 31 percent silt, and 28 percent clay. About 10 feet of till is exposed at the top of the roadcut. Underlying the till is a 4-foot section of hard gray-brown material that contains an abundance of flat sandstone cobbles and is tentatively identified as colluvium. Beneath the colluvium is a section of gravelly clay and sand, possibly of proglacial origin. Gray and brown silts (units 2, 3) exposed at the base of the roadcut are lacustrine deposits which facilitate much of the landsliding in the valley.

Slumping at this roadcut occurs on the clayey silt, which virtually flows when stream erosion or manmade roadcuts relieve horizontal stress. Most of the slumping in the valley is related to the basal clayey silt (unit 2).

TABLE 1.—*Characteristics of glacial deposits in field trip area (based on White, 1960, 1961, 1967, 1969; DeLong and White, 1963; Winslow and White, 1966)*

	Unit	Average composition (%)			Oxidized color	Thickness (ft)	Average depth to base of oxidized and leached horizon	
		Sand	Silt	Clay			(ft)	(in)
Grand River lobe	Hiram Till	12	41	47	Dark brown	0- 30+	3	
	Lavery Till	24	45	31	Dark brown	0- 13	4	7
	Kent Till	37	42	21	Yellow brown	0-100+	5	8
	Mogadore Till	46	43	11	Yellow brown to olive brown	0- 90	7	4
	Titusville Till	43	40	17	Olive brown	0- 15	9	3
Killbuck lobe	Hiram Till	26	46	28	Dark brown	0- 12	2	9
	Hayesville Till	28	46	26	Dark brown	0- 12	4	6
	Navarre Till	44	39	17	Yellow brown	0- 15+	5	4
	Millbrook Till	43	42	15	Yellow brown to olive brown	0- 21	9	3

STOP 2 – EVERETT ROAD

The stratigraphy at the Everett Road section demonstrates a till-silt relationship different from that viewed at Stop 1. Here a till (Kent or Mogadore) underlies the gray clayey silt (unit 2, table 2):

	Thickness (ft)
Silt, yellow-brown, brown, and gray, horizontally bedded (unit 3, table 2)	20
Silt, clayey, gray, massive (unit 2, table 2)	18
Till, gray (5Y 7/1), unoxidized, calcareous, pebbly to bouldery; sand 15 percent, silt 45 percent, clay 40 percent; Kent or Mogadore? (unit 1, table 2)	14
Elevation at road 790 ft	

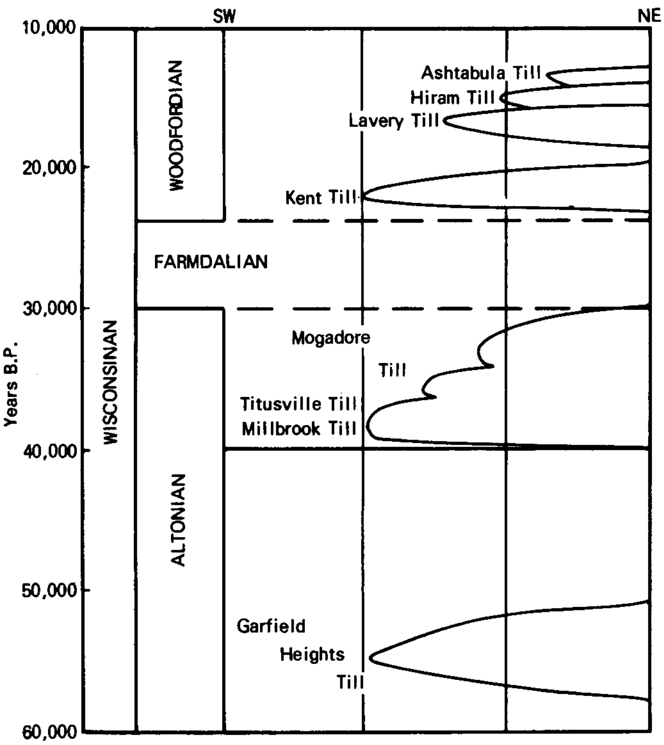

FIGURE 4.—Time-space diagram showing sequence, extent, and age of Wisconsinan tills in the lower Cuyahoga River valley. (Modified from White, 1969; Dreimanis and Karrow, 1972.)

The slide observed on Everett Road is one of many which occur on the slopes of this tributary valley. The sliding mass is composed mainly of silty clays and clayey silts (units 2 and 3, table 2). These soils characteristically have low to medium permeability, high erosion potential, fair to very poor ability to undergo plastic deformation without shearing, and only fair shearing strength. Principal sliding movement occurs along a logarithmic spirally shaped slip plane (high angle at the head, low angle in the middle and lower sections), the base of which is no lower than the road. Evidence for this is: (1) the topographic posture of the slide, (2) the undisturbed nature of the road and slope beyond, and (3) the presence of a gray clayey silt (unit 2) at the base of the sliding mass. Stress-distribution diagrams foŕ slopes show the principal maximum stress vectors concentrating in the middle and lower slopes, with stress direction becoming more horizontal in the lower slope. Thus a weak clay unit, located in the lower slope and having a low friction angle, would enhance basal shear and cause a logarithmic spirally shaped slip plane. Secondary movements have developed on the main sliding mass, adding to the complexity of the topographic posture.

The triggering mechanism of the slide was probably the undercutting of the toe of the slope during road construction. Of equal importance in slide propagation are the geology and geohydrology of the slide. Char-

TABLE 2.—*Engineering properties and composition of materials observed in Cuyahoga River valley near Peninsula*

Unit no.	Description	Engineering properties[1,2]				Composition (%)[1]		
		q_u (tons/ft^2)	w (%)	Lw	PI	Sand	Silt	Clay
5	Till, brown, hard, pebbly; silty clay (Lavery?)	10+ 4-15	10 8-12	32 27-47	9 7-11	33 12-54	34 22-46	32 14-51
4	Sand, brown, crossbedded. Silt lenses, brown							
3	Silt, brownish-yellow	14	11	33 27-38	16 15-18	-	57 41-73	33 14-52
2	Clay, gray, silty; to clayey silt	1.5 0.5-2.5	20 15-25	37 29-46	18 9-27	-	39 17-60	60 40-78
1	Till, gray; clayey silt; dark pebbles (Kent?)	12 7-17	16 11-19	27 23-31	9 6-13	21 15-31	43 38-47	36 31-40

[1]Average values listed first. Usual range in values follows.
[2]q_u = Unconfined compressive strength; w = natural water content, % dry weight; Lw = liquid limit; PI = plasticity index.

acteristically the low-permeability clayey silts are interbedded with lenses of more permeable silty sands and clean sands (unit 4, table 2). During the wet season pore-water pressures can build within these lenses, significantly reducing the shearing resistance of the material. In many places this alone is enough to initiate failure. At this site the added impetus of toe removal was required for failure. Once movement was initiated, disturbance of the flow paths along shear zones increased the pressure and saturation levels, accelerating the slope-degradation processes and creating an increasingly complex slide-flow situation.

The initial movement and ensuing reduced stability left this slope vulnerable to effects of increased saturation and pore-water pressures. Thus during the wet months of late winter and early spring the slide periodically moves out onto the road.

Areal survey shows that much of the slope along this tributary valley is unstable. However, the present status of this slide is not one of pressing concern. The slide itself is not endangering private property or placing undue strain on the local environment. Amelioration of a slide such as this would prove more costly than simply pushing the mud off the road once or twice a year.

STOP 3 – RIVERVIEW ROAD SLIDE

The stratigraphy here (fig. 5) is similar to that at the section exposed at Stop 2. The sequence consists of a laminated yellow-brown silt (unit 3, table 2) overlying a gray clayey silt (unit 2, table 2) and an unoxidized calcareous light-gray (5*Y* 6/1) till (Kent? Till). The till contains 31 percent sand, 38 percent silt, and 31 percent clay (unit 1, table 2) and rests directly on bedrock (Chagrin Shale). Is this the same till we saw at Stop 2? This same relationship–lacustrine silt overlying a till which rests on bedrock–will be seen again at Stop 4.

The slide, located on Riverview Road beneath the Ohio Turnpike bridge, involved mobilization of the gray clayey silt (unit 2) overlying the Kent(?) Till (unit 1) and of the laminated yellow-brown silt (unit 3) along steep vertical slip planes and along the Chagrin Shale (Devonian) bedrock surface at the base (fig. 5). The initial causes of slope instability at this site were probably, first, removal of trees by a windstorm and, second, an increase in water from drainage off the Ohio Turnpike bridge. The trees aided slope stability by sapping water from the soil and holding the slope intact. An adjacent foliated slope shows no signs of

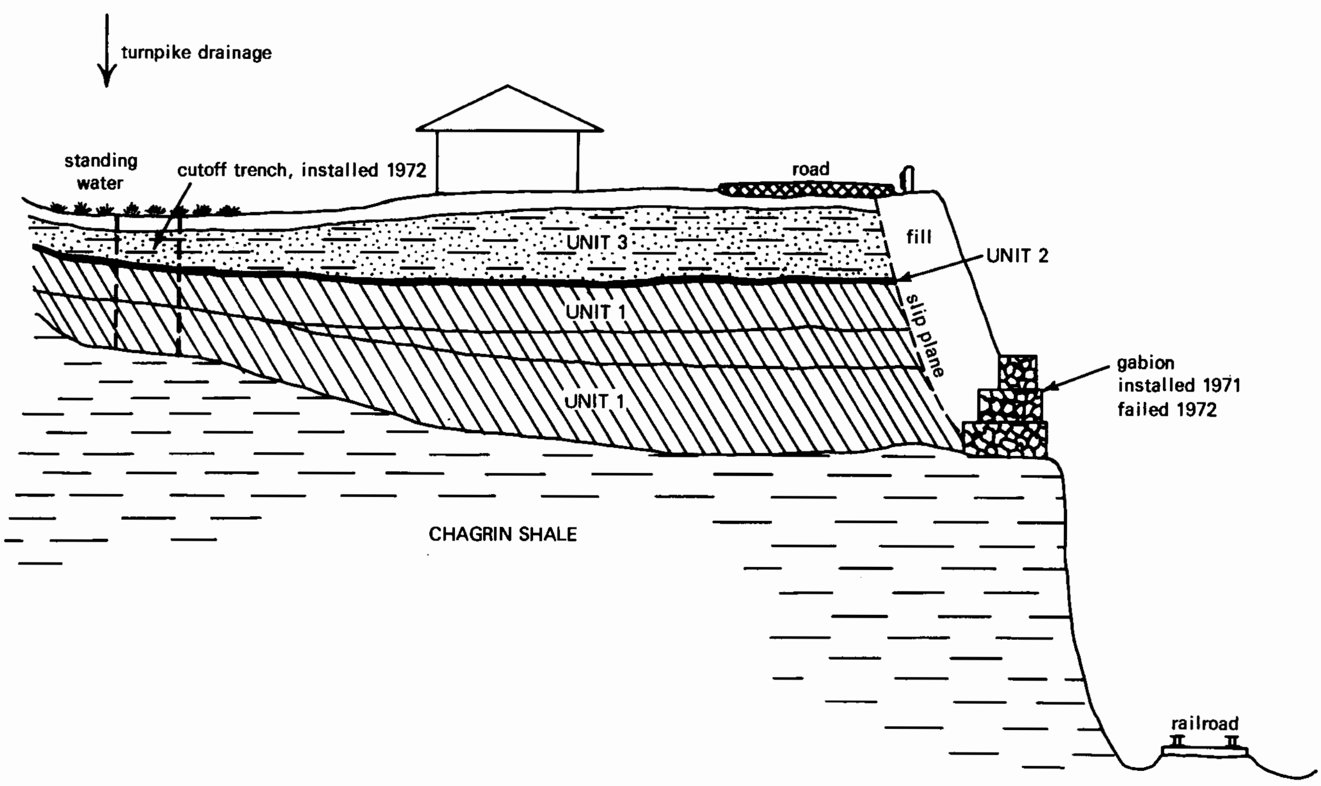

FIGURE 5.–Diagrammatic sketch (not to scale) showing Riverview Road slide beneath Ohio Turnpike bridge (Stop 3). The units referred to in the diagram are explained in table 2.

movement, yet conditions are similar to those at the slide site. Pipes and ditches from the Ohio Turnpike bridge empty below the bridge into a low area, where ponding occurs. The effect is to increase the seepage above levels experienced before the construction of the bridge.

The initial slide scar was refilled with silt behind pyramidal-shaped brick-filled cribs (gabions). During the early spring, water which seeped along bedding planes in the yellow-brown silt (unit 3) met the semi-permeable fill material at the slip plane. The fill became saturated, and excessive pore-water pressure developed along the slip plane. The slope failed again, removing part of the road and burying a section of the railroad.

The suggested method of amelioration was to intercept the ground-water seepage with a cutoff trench that would be excavated to bedrock and that would drain the surface and subsurface waters parallel to the sliding slope. The cutoff trench was constructed in 1972, and a layer of gravel was placed horizontally on the base and vertically on the scar of the slide excavation as an added precaution to insure the long-term stability of the slope. However, no retaining structure was built to hold the gravel in place, and erosion by road runoff has washed most of it away.

STOP 4 – BOSTON MILLS SKI AREA

The generalized geologic section of the Boston Mills ski area is as follows:

		Thickness (ft)
Unit 5	Till, yellow-brown (5Y 5/3); blocky clayey silt with thin sand and silt lenses (Defiance Moraine)	40+
Unit 4	Sand, brown and white, clean to silty, fine- to medium-grained, crossbedded	30+
Unit 3	Silt, yellow-brown, hard	5
Unit 2	Silt, dark-gray, clayey	10+
Unit 1	Till, dark-gray, hard, pebbly; with sand and silt lenses; sand 17 percent, silt 47 percent, clay 36 percent	20+
Bedrock	Chagrin Shale	

The stratigraphy at this stop suggests that the lacustrine silt is sandwiched between at least two tills. The basal till in this area should be either the Kent or the Mogadore. This lower till, however, has a high clay content, giving it quite a different texture from that typical of these tills (see table 1). Is this the valley equivalent, enriched in locally derived clay, of the Kent or Mogadore Till?

The thickness of the upper till at this stop is possibly the result of stacking as the ice moved out of the valley over the northwest-southeast-trending elongate bedrock hill that lies immediately to the southwest (see fig. 2).

The slope at this stop is undercut by piping, a process in which material is removed at the base, causing the slope above to calve. The materials involved in piping at this locality are lenses of highly permeable clean sand interbedded with sandy silt (units 3 and 4). These materials rest on low-permeability till (unit 1), which overlies the Chagrin Shale (fig. 6). Such materials, under the geologic and geohydrologic conditions that exist at this stop, are very susceptible to piping and erosion. Prior to development for skiing, the slope had a thick foliage cover, a well-developed soil profile, and no piping problems. Defoliation and removal of the soil mantle exposed the underlying sand and silt beds, allowing the ground water to escape freely from the base. This initiated the piping, which has rendered the slope useless for skiing, has caused financial loss to the developer, and has created a potential hazard.

The original slope was considerably steeper, as can be seen to the north. Such steep slopes are generally considered to be more subject to slumping than gentler slopes. This site illustrates that flattening a slope is not necessarily a solution to slumping; instead a new problem may be created.

STOP 5 – BOSTON MILLS ROAD BENEATH THE I-271 BRIDGE

The drainage design at this locality is adequate for most soil conditions. This site, however, is an exception. For the most part the soils are silty clays, clayey silts, and some sands (units 3 and 4) with very high erosion potential. Highway borings at and near this site (fig. 7) indicate a thickness of almost 100 feet of silt. Running water has undermined the riprap-filled drainage ditch by eroding soil from beneath the riprap, ultimately causing the drainage within the ditch to bypass the culvert. Water now runs across the road and into the stream, increasing discharge and sediment load of the stream. Even if the water had entered the culvert as designed, the storm drains would have rapidly silted up, causing similar problems.

A proper drainage material would have been slag such as that used beneath the overpass. Slag would have permitted movement of water at a rate adequate to get it off the hill without causing erosion. Again, proper site evaluation could have avoided such results.

An additional problem was encountered at this site during construction of the overpass. The initial design called for use of compacted silt for abutment foundation material. After emplacement of the abutment the silt failed and the top of the south abutment was 2 feet lower than the top of the north abutment. At considerable expense this was corrected by removal of the abutment and addition of a slag fill. Construction and

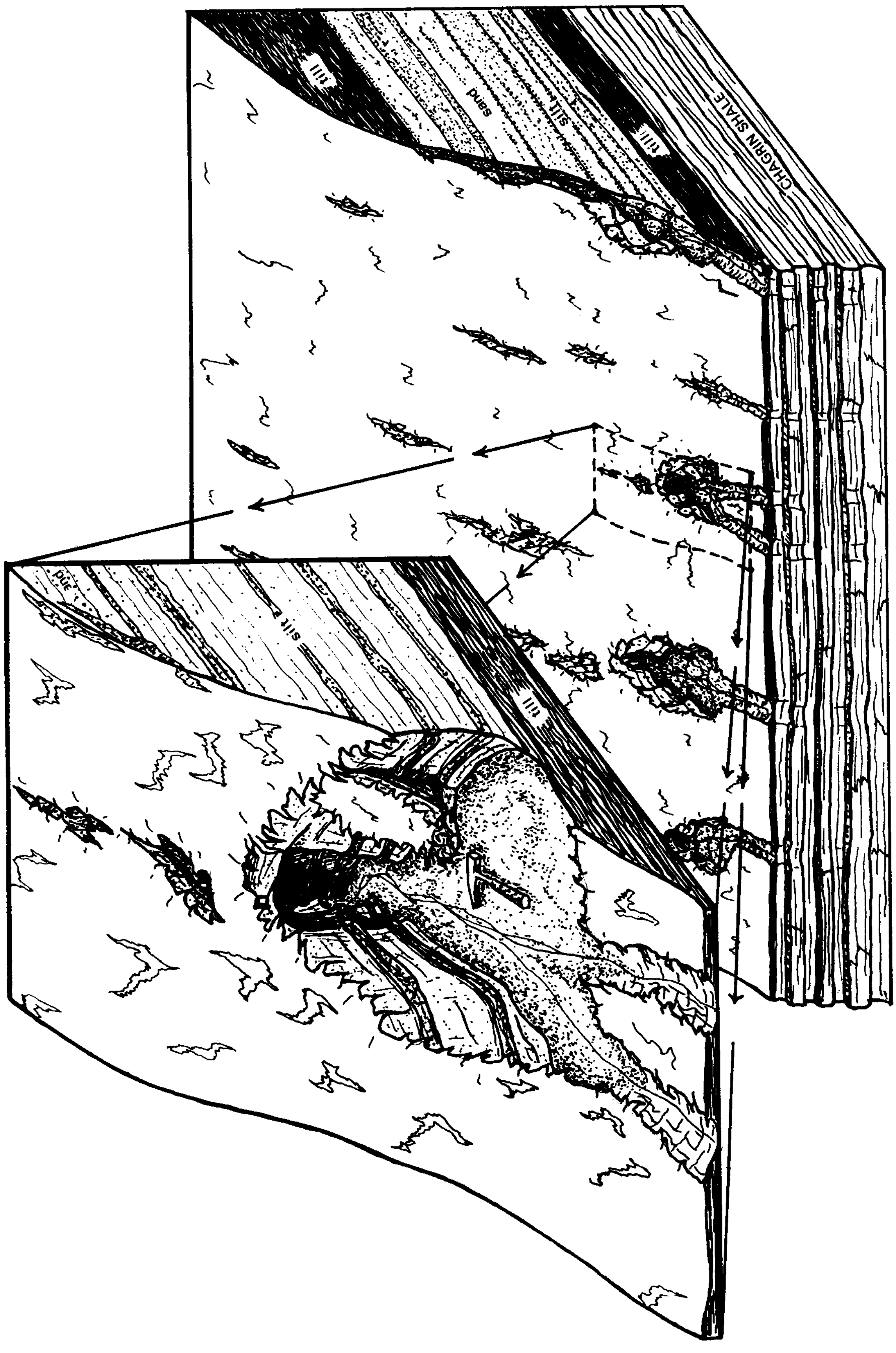

FIGURE 6.--Diagrammatic interpretation of piping along north side of Boston Mills ski slope (Stop 4). (Not to scale; modified from Gardner, 1972.)

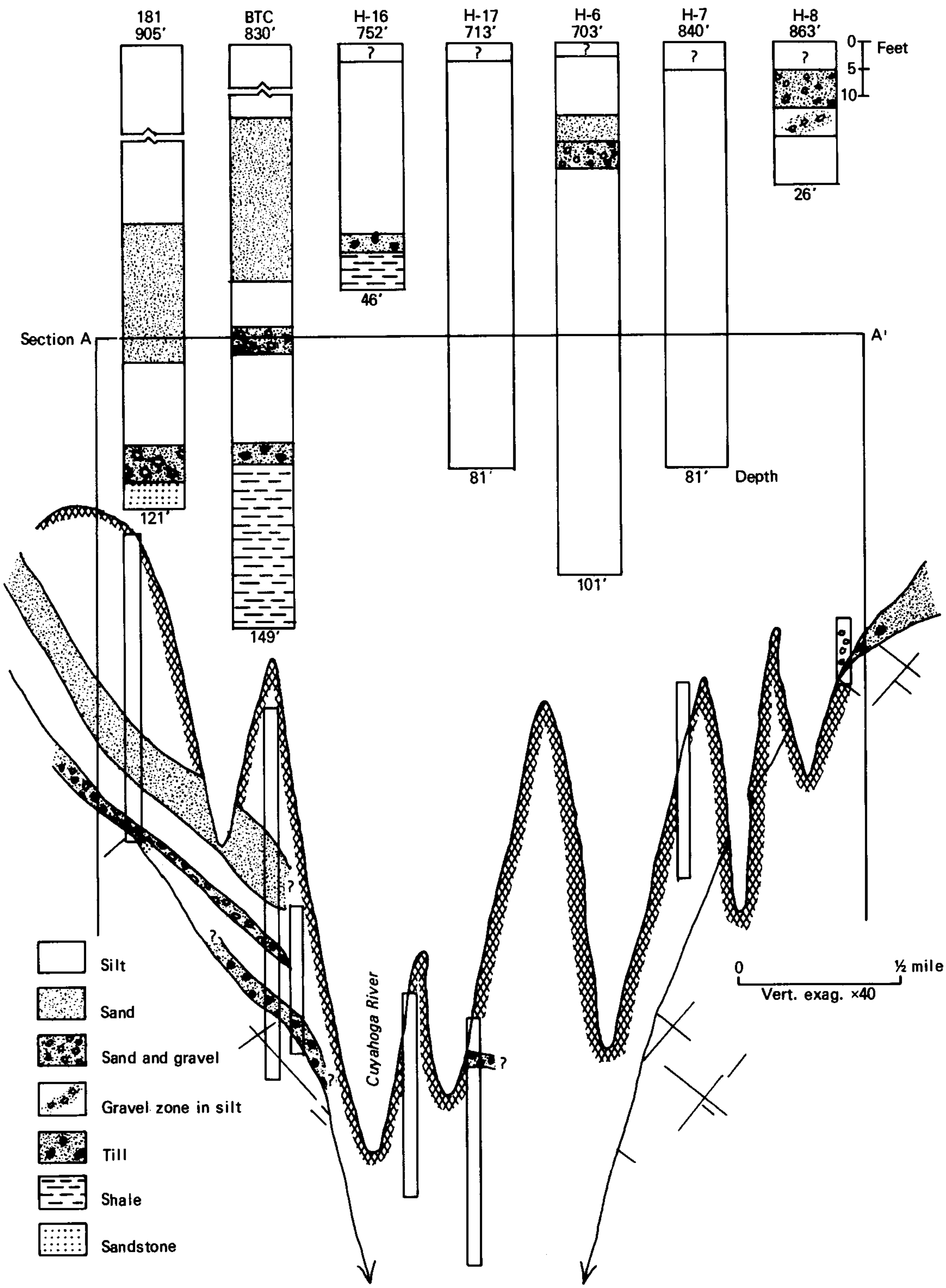

FIGURE 7.—Cross section along line A-A' of figure 1, showing relationship between tills, outwash (sand and gravel), lacustrine silt, and bedrock topography. Measured section BTC, and highway exploration cores H-16, H-7, and H-8 are located near but not on line A-A'. These have been superimposed on the topographic profile made along A-A'. Thicknesses of lithologic units in the cross section are diagrammatic. (Modified from Wittine, 1970.)

maintenance of the Interstate highways in the valley have been constantly hampered by slope-stability problems in the silts and clays.

The slide adjacent to this site occurred in the same type of soil materials seen at the previous stop. The situation here is somewhat similar to that observed at Stop 2, the Everett Road area; however, this slide affects private property and dwellings. The geologic, geohydrologic, and soil behavioral characteristics are, once again, conducive to sliding. The soils, clayey silts and silty clays, with a few sand lenses, characteristically have high erosion and piping potential, fair shearing resistance, and only fair-to-poor ability to undergo plastic deformation without shearing. These soils occur in thick (1-3 ft) to thin (1 in-1 ft) interbeds and lenses on this hillslope. The triggering mechanism initiating sliding was probably undercutting of the toe of the slope during road construction. Planes of weakness also could have developed earlier as a result of natural undercutting by the stream. However, the current configuration of the slide indicates sliding impetus was provided by the roadcut.

As in the Everett Road slide (Stop 2), increased pore-water pressure during the wet season plays a key role in the degradation of this slope by periodically reactivating the slide. The slide itself is rotational and retrogressive in nature, with a near circular slip plane complexed by secondary slip planes developed within the sliding mass. The maximum depth of the primary slip plane is estimated to be 300 feet beneath the center of the slope. The difference in symmetry between the Everett Road slide and this one is explained by the occurrence and location of the gray clay (unit 2, table 2). In the Everett Road slide the low-shearing-strength clay unit is located at the base of the slope; thus stress distribution within the slope causes failure along the clay unit, as discussed in the description of Stop 1. The materials in the Boston Mills Road slide are quasihomogeneous (different beds acting as one unit); therefore the shear planes develop along the more ideal circular arc.

In 1971 several lines of pipes were installed on this slope to monitor earth movements. The attitudes of the pipes in 1973 indicate the amounts of movement in various areas.

As you drive to Stop 6 take notice of (1) the newly asphalted semicircular bumps in the road, (2) the topographic postures of the slopes, both above and below the road, and (3) the attitudes of the trees on those slopes. Almost the entire slope on Boston Mills Road, from Stop 5 one-half mile up the road toward Stop 6, is mobilized to some extent.

STOP 6 – BOSTON MILLS ROAD ON SOUTHWEST SIDE OF THE OHIO TURNPIKE OVERPASS

The roadcut at Stop 6 exposes soil materials (units 2, 3, and 4) similar to those observed at the previous locations. The point of interest at this stop is the difference in topographic postures of the slopes on opposite sides of the road. Slope-degradation processes have decidedly affected the north-facing slope more than the south-facing slope. This is caused in part by the increased and prolonged saturation conditions on the north-facing slope. The south-facing slope receives direct radiation from the sun most of the daylight hours all year; the north-facing slope receives no direct sunlight except in late spring and then only for a few hours. This greatly affects the depth of saturation of the soils on this slope. The south-facing slope is usually noticeably drier. The exposure factor is even more significant along I-271 roadcuts leading into the valley.

STOP 7 – SLOPE ADJACENT TO THE EASTERN OHIO TURNPIKE BRIDGE ABUTMENT

The value of geomorphology and botany in recognizing potential problem areas and in distinguishing various land-use qualities cannot be overemphasized. Knowledge of these fields is an essential starting point in any evaluation, and is of value in providing focal points and guidelines for further investigation. In conjunction with such knowledge aerial photography is a very powerful tool with which to decipher geology and to recognize geohydrologically and botanically interacting areas much more quickly and easily than was possible with earlier methods.

The slope adjacent to the eastern bridge abutment of the Ohio Turnpike exemplifies the stability problems common throughout the lower Cuyahoga valley. Although the geology, the geohydrology, and the behavior characteristics of the soils are difficult to determine by simple field investigation because of the vegetative cover and lack of clean outcrops, distinctive surface features exhibited by this slope indicate that conditions are conducive to sliding.

Field evidence indicating active movement on this slope is multifold. The ground surface is scarred with numerous tension cracks and slide scarps. The lineations caused by these scars are quite apparent on aerial photos. In addition the history of slide movement can be deciphered in many places from the trunks and growth patterns of the trees. The attitudes and trunk shapes of the trees typify those on slumping slopes. Sliding is for the most part rotational and retrogressive in nature, with the major shear surface estimated to have a maximum depth of 40 feet and to lie at approximately 19° from the horizontal (this angle coincides with the laboratory-determined residual angle of internal friction). Sliding was probably initiated by oversteepening and undercutting of the toe by the Cuyahoga River, which ran along this flank of the valley before rerouting. Movement is continued by undercutting of the toe by headward-eroding intermittent streams, with the possibility of piping occurring in the sand units at the base of the slide. Increased pore-water pressure during the wet season also plays a key role in slide activation. Excavation for turnpike fill of the till above the slope enhances the seepage by exposing the silty soils and by providing for water impoundment in the recharge area. Absence of trees, which can sap significant volumes of water, also enhances seepage and pore-water-pressure effects.

As one can see, the entire slope is mobilized. The slope mobilization in the area typifies movement on many slopes within the valley. A small bump on the road, such as seen on Boston Mills Road between Stops 5 and 6, may actually be a small part of an extensive slide system. Other roads with similar conditions include Highland Road, Columbia Road, and Yellow Creek Road. If these conditions had been recognized and anticipated in planning and construction of the various roads which cross the valley, man-hours, materials, costs, and delays might have been reduced considerably.

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